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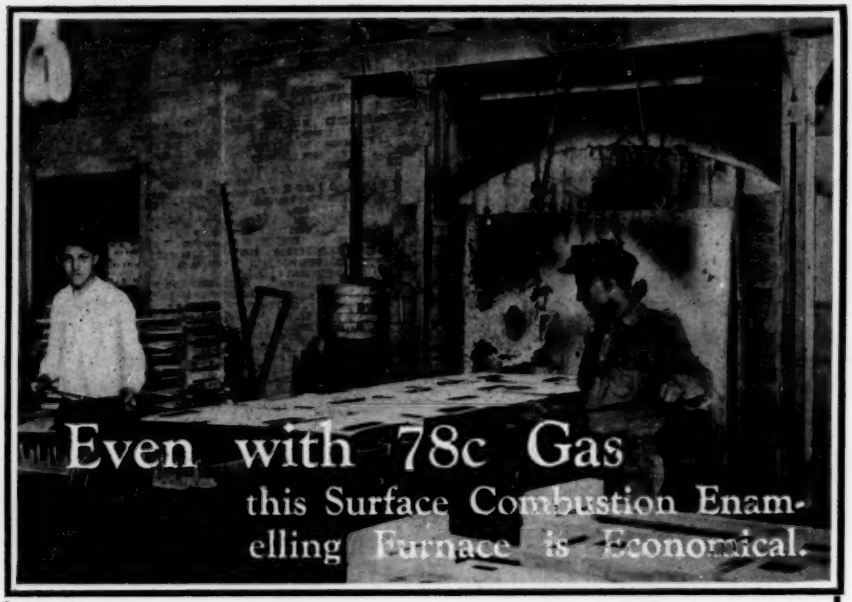

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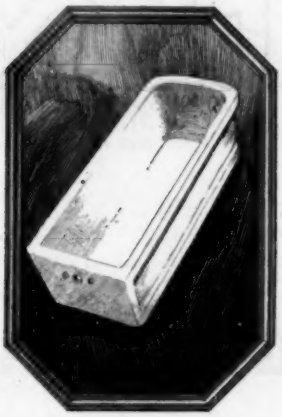

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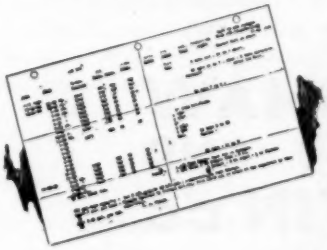

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ORIGINAL PAPERS

CLAY SEWER PIPE MANUFACTURE.—IV. THE INFLUENCE OF DIFFERENT SALT GLAZING TEMPERATURES UPON THE COLOR AND GLOSS OF GLAZES OBTAINED ON CLAYS WITH VARYING SILICA, ALUMINA, AND IRON OXIDE CONTENTS[1]

By H. G. Schurecht[2]

ABSTRACT

Object.—A study was made of the effects of different salt glazing temperatures upon the color and brightness of salt glazes produced upon clays with varying silica, alumina, and iron oxide contents.

Results.—In tests conducted in commercial kilns operating under normal conditions, it was found that increasing the salt glazing temperatures has a tendency to produce duller and darker glazes on clays containing iron oxide.

The brightness of the glazes produced may be approximately represented by the following formula:

$$-1.00x_1 + 0.376x_2 - (1.885 + 0.385(1.01253)^{(T-1110)})x_3 = 100G$$

x_1, x_2 and x_3 represent the percentages of silica, alumina and iron oxide, respectively. T is the salt glazing temperature in °C. When G was greater than 0, the glazes were bright; when between −0.1337 and 0 they were semi matt; and when less than −0.1337 they were matt.

The color obtained may be approximately represented by the following formula:

$$10.3x_1 - 2.65x_2 + (14.6 + 54.1\ (1.0066)^{(T-1110)})x_3 = 100C$$

[1] Published through the courtesy of the Eastern Clay Products Association and the Clay Products Association under whose auspices this work has been done as part of their research program on the manufacture of clay sewer pipe.

[2] Senior Fellow, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa.

When C was between 0 and 2, white to tan glazes were produced; when between 2 and 3.5, light brown glazes were obtained; when between 3.5 and 4.75, brown glazes were produced; when between 4.75 and 8.2, mahogany colors were obtained; and when above 8.2, dark brown to black glazes were produced.

Clays containing a high iron oxide content should be salt glazed at low temperatures while clays containing a low iron oxide content should be glazed at high temperatures to produce the best glazes. Decreasing the iron oxide and alumina contents will improve the brightness of the salt glazes. High alumina clays will produce darker colors than high silica clays with the same percentage of iron oxide.

Introduction

Where it is not possible to test the strength of sewer pipe the quality of pipe is most commonly judged by their appearance. Sewer pipe with dense bodies and dark brown or mahogany bright glazes are usually selected in preference to lighter colored pipe or pipe with dull rough glazes. Judging the quality of pipe by their color is misleading since pipe of light color may be far superior to certain dark colored pipe, but their less pleasing appearance is, unfortunately, often the cause of their rejection. The density of the body and the brightness or smoothness of the glaze are much better criterion for judging the quality of sewer pipe.

One of the most important methods of controlling the smoothness and color of sewer pipe is by means of their salt glazing temperatures which vary between wide limits. The temperatures at which sewer pipe are now being salt glazed vary from cone 02, 1922°F to cone 10, 2426°F. The temperatures obtained in different portions of the same kiln may vary as much as 10 cones, 360°F. This work was done to determine how much the brightness and color of glazes are affected by different salt glazing temperatures.

Sufficient has already been done to show that it is possible to salt glaze sewer pipe at too low as well as at too high temperatures, depending largely upon the content of iron compounds present and also to a lesser extent upon the contents of alumina and silica in the clay.

Experimental Methods

The 36 synthetic clays previously tested[1] containing varying amounts of silica, alumina and iron oxide were also studied in this work. These three ingredients were varied between the following limits:

Alumina (Al_2O_3)	12.30 to 37.18 per cent.
Silica (SiO_2)	38.41 to 80.95 per cent.
Iron Oxide (Fe_2O_3)	0.33 to 16.40 per cent.

The mixtures were prepared by adding varying amounts of potter's flint and iron oxide to a 1:1 Florida kaolin: Tennessee ball clay mixture.

[1] "The Effect of Variable Alumina, Silica and Iron Oxide in Clays on Some Properties of Salt Glazes," *Jour. Amer. Ceram. Soc.*, **6** [6], 717–29(1923).

The clays used had compositions approaching closely the analyses of pure clay. In Tables I and II are given the compositions of both the raw and fired samples, respectively. All of the ingredients were screened through a 100-mesh sieve before mixing.

The mixtures were molded into bars which were set in fire clay plaques. These were fired and salt glazed in commercial sewer pipe kilns at cone 02, cone 3, cone 7 and cone 10.

TABLE I

THE CHEMICAL COMPOSITION OF THE RAW MIXTURES

No.	Alumina, Al_2O_3	Silica, SiO_2	Iron oxide, Fe_2O_3	Titanium oxide, TiO_2	Calcium oxide, CaO	Magnesium oxide, MgO	Alkalies $Na_2O + K_2O$	Sulphur S	Water, H_2O
A-1	31.41	38.81	16.30	0.23	0.21	0.02	0.83	0.03	12.20
A-3	23.89	53.65	12.29	0.17	0.16	0.02	0.54	0.02	9.26
A-5	19.80	62.80	9.82	0.13	0.12	0.01	0.41	0.01	7.48
A-7	16.13	68.70	8.17	0.11	0.10	0.01	0.38	0.01	6.31
A-9	13.96	73.20	6.99	0.10	0.09	0.01	0.33	0.01	5.46
A-11	12.30	76.28	6.10	0.08	0.07	0.01	0.30	0.01	4.82
C-1	31.62	39.15	15.73	0.22	0.21	0.02	0.70	0.02	12.39
C-3	24.44	55.02	10.16	0.17	0.15	0.02	0.55	0.01	9.53
C-5	19.63	63.99	8.10	0.12	0.11	0.01	0.44	0.01	7.67
C-7	16.41	69.84	6.71	0.10	0.09	0.01	0.38	0.01	6.41
C-9	14.18	74.21	5.86	0.09	0.08	0.01	0.33	0.01	5.44
C-11	12.47	77.22	4.98	0.07	0.06	0.01	0.30	0.01	4.69
E-1	33.55	41.42	10.68	0.24	0.22	0.02	0.73	0.02	13.12
E-3	25.18	56.25	7.94	0.16	0.10	0.02	0.55	0.01	9.80
E-5	20.07	65.18	6.29	0.12	0.08	0.01	0.45	0.01	7.32
E-7	16.71	70.81	5.22	0.10	0.08	0.01	0.38	0.01	6.54
E-9	14.20	75.13	4.29	0.09	0.08	0.01	0.34	0.01	5.56
E-11	12.61	78.00	3.88	0.08	0.07	0.01	0.29	0.01	4.94
G-1	34.15	42.25	8.95	0.24	0.21	0.02	0.72	0.02	13.45
G-3	25.89	57.69	5.41	0.17	0.16	0.02	0.56	0.01	10.08
G-5	20.44	66.39	4.44	0.14	0.12	0.01	0.45	0.01	8.00
G-7	17.04	72.00	3.68	0.12	0.10	0.01	0.38	0.01	6.66
G-9	14.60	75.98	3.10	0.10	0.09	0.01	0.34	0.01	5.73
G-11	12.70	79.01	2.73	0.08	0.08	0.01	0.30	0.01	5.01
I-1	35.92	44.37	4.34	0.24	0.22	0.02	0.78	0.02	14.12
I-2	26.40	59.10	3.19	0.15	0.17	0.02	0.58	0.01	10.37
I-3	20.94	67.85	2.52	0.14	0.15	0.01	0.46	0.01	8.11
I-4	17.29	73.25	2.04	0.12	0.11	0.01	0.38	0.01	6.78
I-5	14.87	77.19	1.77	0.11	0.10	0.01	0.33	0.01	5.81
I-6	12.91	79.99	1.55	0.09	0.09	0.01	0.29	0.01	5.06
K-1	37.18	46.00	0.88	0.25	0.21	0.02	0.78	0.02	14.64
K-3	27.14	60.50	0.65	0.19	0.18	0.02	0.58	0.01	10.73
K-5	21.40	68.90	0.52	0.15	0.14	0.01	0.46	0.01	8.41
K-7	17.69	74.30	0.44	0.12	0.13	0.01	0.38	0.01	6.92
K-9	15.02	78.17	0.37	0.10	0.10	0.01	0.33	0.01	5.89
K-11	13.10	80.95	0.33	0.09	0.09	0.01	0.29	0.01	5.13

TABLE II

THE CHEMICAL COMPOSITION OF THE MIXTURES AFTER FIRING

No.	Alumina, Al_2O_3	Silica, SiO_2	Iron oxide, Fe_2O_3	Titanium oxide, TiO_2	Calcium oxide, CaO	Magnesium oxide, MgO	Alkalies, $Na_2O + K_2O$
A-1	35.80	44.18	18.70	0.26	0.24	0.02	0.80
A-3	26.28	59.18	13.55	0.19	0.18	0.02	0.60
A-5	21.25	67.50	10.53	0.14	0.13	0.01	0.44
A-7	17.25	73.40	8.70	0.12	0.11	0.01	0.41
A-9	14.80	77.52	7.40	0.11	0.11	0.01	0.35
A-11	12.97	80.10	6.40	0.10	0.10	0.01	0.31
C-1	36.10	44.65	17.93	0.26	0.24	0.02	0.80
C-3	27.04	60.75	11.23	0.19	0.17	0.02	0.61
C-5	21.25	69.29	8.77	0.10	0.10	0.01	0.48
C-7	17.57	74.62	7.20	0.10	0.09	0.01	0.41
C-9	14.95	78.30	6.20	0.10	0.09	0.01	0.35
C-11	13.12	81.20	5.23	0.07	0.06	0.01	0.31
E-1	38.63	47.64	12.23	0.28	0.25	0.02	0.88
E-3	27.80	62.33	8.80	0.23	0.22	0.02	0.61
E-5	21.77	70.50	6.82	0.21	0.20	0.01	0.48
E-7	17.86	75.75	5.60	0.19	0.18	0.01	0.41
E-9	15.10	79.75	4.50	0.15	0.13	0.01	0.36
E-11	13.28	82.10	4.10	0.10	0.09	0.01	0.31
G-1	39.48	48.85	10.30	0.28	0.24	0.02	0.83
G-3	28.80	64.16	6.03	0.19	0.18	0.02	0.82
G-5	22.30	72.16	4.78	0.15	0.13	0.01	0.49
G-7	18.30	77.00	3.94	0.13	0.11	0.01	0.41
G-9	15.53	80.60	3.29	0.11	0.10	0.01	0.86
G-11	13.41	83.20	2.88	0.09	0.09	0.01	0.32
I-1	41.90	51.59	5.06	0.28	0.26	0.02	0.90
I-3	29.40	66.02	3.56	0.19	0.17	0.02	0.65
I-5	22.75	73.68	2.74	0.16	0.16	0.01	0.50
I-7	18.56	78.60	2.16	0.13	0.12	0.01	0.42
I-9	15.72	81.80	1.88	0.12	0.11	0.01	0.36
I-11	13.62	84.20	1.63	0.10	0.10	0.01	0.36
K-1	43.48	54.00	1.03	0.29	0.27	0.02	0.91
K-3	30.27	67.70	0.73	0.21	0.20	0.02	0.87
K-5	23.41	75.20	0.57	0.16	0.15	0.01	0.50
K-7	19.00	79.84	0.47	0.14	0.13	0.01	0.41
K-9	16.00	83.03	0.39	0.11	0.11	0.01	0.35
K-11	13.80	85.33	0.35	0.10	0.10	0.01	0.31

Experimental Results

The Effect of Varying Salt Glazing Temperatures upon the Glossiness of Salt Glazes

The influence of different salt glazing temperatures upon the smoothness and brightness of salt glazes is shown graphically in Figures 1, 2, 3 and 4. Salt glazing clays at higher temperatures will produce duller glazes on clays containing a high content of iron oxide than when they are salt glazed at low temperatures, see Table III.

TABLE III

THE BRIGHTNESS OF GLAZES OBTAINED ON THE MIXTURES AT DIFFERENT TEMPERATURES

No. of mixture	Cone 02	Cone 3	Cone 7	Cone 10
A-1	Matt	Matt	Matt	Matt
A-3	Matt	Matt	Matt	Matt
A-5	Matt	Matt	Matt	Matt
A-7	Semi Matt	Matt	Matt	Matt
A-9	Semi Matt	Semi Matt	Matt	Matt
A-11	Bright	Semi Matt	Semi Matt	Matt
C-1	Matt	Matt	Matt	Matt
C-3	Matt	Matt	Matt	Matt
C-5	Matt	Matt	Matt	Matt
C-7	Semi Matt	Semi Matt	Matt	Matt
C-9	Bright	Semi Matt	Matt	Matt
C-11	Bright	Bright	Semi Matt	Matt
E-1	Matt	Matt	Matt	Matt
E-3	Matt	Matt	Matt	Matt
E-5	Semi Matt	Matt	Matt	Matt
E-7	Semi Matt	Semi Matt	Matt	Matt
E-9	Bright	Bright	Semi Matt	Matt
E11	Bright	Bright	Semi Matt	Matt
G-1	Matt	Matt	Matt	Matt
G-3	Matt	Matt	Matt	Matt
G-5	Semi Matt	Semi Matt	Matt	Matt
G-7	Bright	Semi Matt	Semi Matt	Matt
G-9	Bright	Bright	Semi Matt	Semi Matt
G-11	Bright	Bright	Bright	Semi Matt
I-1	Matt	Matt	Matt	Matt
I-3	Matt	Matt	Matt	Matt
I-5	Semi Matt	Semi Matt	Semi Matt	Matt
I-7	Bright	Bright	Semi Matt	Semi Matt
I-9	Bright	Bright	Bright	Bright
I-11	Bright	Bright	Bright	Bright
K-1	Matt	Matt	Matt	Matt
K-3	Semi Matt	Semi Matt	Semi Matt	Semi Matt
K-5	Bright	Bright	Bright	Bright
K-7	Bright	Bright	Bright	Bright
K-9	Bright	Bright	Bright	Bright
K-11	Bright	Bright	Bright	Bright

The results can be approximately expressed much simpler by means of the following formula:

$$g_1x_1 + g_2x_2 + g_3x_3 = 100G \qquad (1)$$

x_1, x_2 and x_3 represent the percentages of alumina, silica and iron oxide, respectively, in the clay in terms of calcined weight. g_1 and g_2 represent the gloss factors for alumina and silica, which were found to be -1.00 and $+0.376$, respectively. The value g_3 which represents the gloss factors

for iron oxide was found to vary from −2.27 to −7.85 depending upon the salt glazing temperature. This factor was found to be −2.27 at cone 02, −2.923 at cone 3, −4.75 at cone 7, and −7.85 at cone 10, see Figure 5.

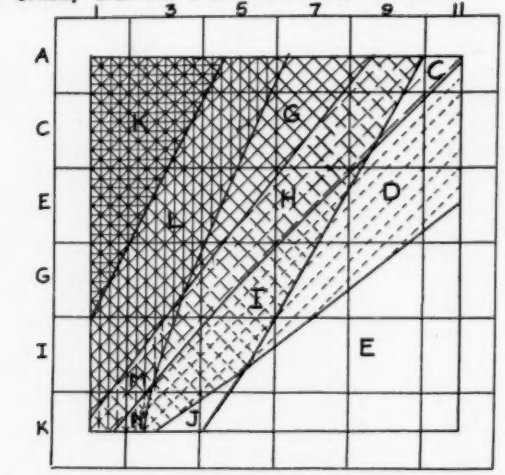
The value of g_2 may also be calculated for different temperatures by means of the following equation in which T is the salt glazing temperature in degrees Centigrade.

$$g_3 = -1.885 - 0.385\ (1.01253)^{(T-1110)} \qquad (2)$$

The observed values for g_3 and those calculated by equation 2 are given below:

Temperature, °C.	Observed value for g_3	Calculated value for g_3
1110	−2.270	−2.270
1190	−2.923	−2.928
1270	−4.750	−4.710
1330	−7.850	−7.851

Figure 1.
The color and gloss of salt glazes obtained at cone 02 on clays of varying silica, alumina and iron oxide contents.



C- Brown Bright.
D-Light Brown Bright.
E-White to Tan Bright.
G-Mahogany Semi Matt.
H-Brown Semi Matt.
I-Light Brown Semi Matt.
J-White to Tan Semi Matt.
K-Dark Brown to Black Matt.
L-Mahogany Matt.
M-Brown Matt.
N-Light Brown Matt.

G in equation 1, represents the gloss factor of the glaze produced with this clay and increases in proportion to the brightness and smoothness of the glaze. When G is greater than 0, the clay will produce a bright glaze provided it is fired under conditions similar to those under which the test pieces were fired.

When G is between −0.1337 and 0, the glazes will be semi matt and when below −0.1337 they will be matt.

The glazes which may be obtained on a clay in which the chief ingredients are silica, alumina, and iron oxide may vary in gloss considerably, depending upon the temperature at which it is salt glazed. The maximum percentages of iron oxide allowable in clays to produce bright and semi matt glazes at different salt glazing temperatures are given below:

Ratio of per cent silica to per cent alumina	Appearance	Cone 02	Cone 3	Cone 7	Cone 10
2	Bright	.. [1]	..	..	..
	Semi Matt	2.23	1.78	1.07	0.64
4	Bright	4.26	3.34	2.08	1.27
	Semi Matt	9.90	7.75	4.84	2.95
6	Bright	7.32	5.79	3.64	2.23
	Semi Matt	12.75	10.10	6.35	3.90

[1] The alumina content is too high to produce bright glaze.

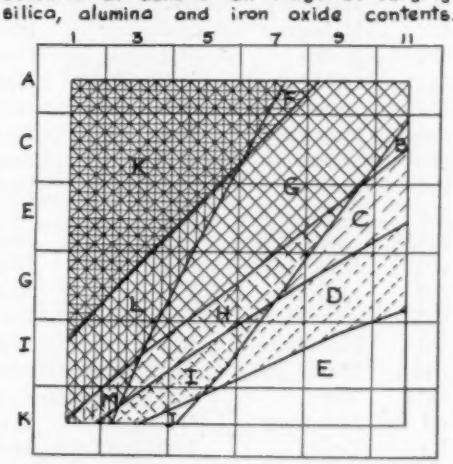
The dulling effect of iron compounds in glazes at high temperatures is probably due to the transition of ferric compounds to ferrous compounds which takes place more readily at high temperatures than at low temperatures.

The Effects of Varying Firing and Salt Glazing Temperatures upon the Color of Salt Glazes

In Figures 1, 2, 3 and 4 and Table IV are shown the effects of different salt glazing temperatures upon the color of salt glazes. This data represents the results obtained in commercial kilns where firing and salt glazing was done under normal conditions. It is possible to obtain darker colors than those obtained in these tests by firing with a reducing kiln atmosphere or lighter colors by firing with an extremely oxidizing atmosphere. These tests apply more closely to clays in which the chief constituents are silica, alumina, and iron oxide, the other ingredients totalling to less than 1 per cent.

This data shows that salt glazing clays at higher temperatures darken the color of the pipe. With low silica clays the desirable brown and mahogany colors are obtained at cone 02, with clays containing 4.2 to 10.0 per cent iron oxide, at cone 3. These same colors are produced on

Figure 2.
The color and gloss of salt glazes obtained at cone 3 on clays of varying silica, alumina and iron oxide contents.



B- Mahogany Bright.
C- Brown Bright.
D- Light Brown Bright.
E- White to Tan Bright.
F- Dark Brown to Black Semi Matt.
G- Mahogany Semi Matt.
H- Brown Semi Matt.
I- Light Brown Semi Matt.
J- White to Tan Semi Matt.
K- Dark Brown to Black Matt.
L- Mahogany Matt.
M- Brown Matt.

clays containing 2.7 to 6.2% iron oxide; at cone 7 they are obtained with clays containing 1.7 to 4.0% iron oxide; and at cone 10, they are produced on clays containing 1.3 to 2.9% iron oxide. As the silica content is increased more iron oxide is required to produce the same colors.

The percentages of iron oxide necessary to produce the desirable brown color at different temperatures with clays containing variable amounts of silica and alumina are given below:

Ratio of per cent silica to per cent alumina	Cone 02	Cone 3	Cone 7	Cone 10
2	4.2 to 10.0	2.7 to 6.2	1.7 to 4.0	1.3 to 2.9
4	5.2 to 12.0	3.4 to 7.8	2.2 to 5.0	1.6 to 3.7
6	6.2 to 13.0	4.0 to 8.4	2.6 to 5.4	1.9 to 4.0

TABLE IV

THE COLOR OF GLAZES OBTAINED ON THE MIXTURES AT DIFFERENT TEMPERATURES

No. of mixtures	Cone 02	Cone 3	Cone 7	Cone 10
A-1	Black	Black	Black	Black
A-3	Dark brown	Black	Black	Black
A-5	Mahogany	Black	Black	Black
A-7	Mahogany	Dark brown	Black	Black
A-9	Brown	Mahogany	Black	Black
A-11	Brown	Mahogany	Dark brown	Black
C-1	Black	Black	Black	Black
C-3	Dark brown	Black	Black	Black
C-5	Mahogany	Dark brown	Black	Black
C-7	Mahogany	Mahogany	Black	Black
C-9	Brown	Mahogany	Dark brown	Black
C-11	Light brown	Mahogany	Mahogany	Black
E-1	Dark brown	Black	Black	Black
E-3	Mahogany	Dark brown	Black	Black
E-5	Mahogany	Mahogany	Black	Black
E-7	Brown	Mahogany	Dark brown	Black
E-9	Light brown	Brown	Mahogany	Black
E-11	Light brown	Brown	Mahogany	Dark brown
G-1	Dark brown	Dark brown	Black	Black
G-3	Mahogany	Mahogany	Black	Black
G-5	Brown	Mahogany	Dark brown	Black
G-7	Light brown	Brown	Mahogany	Dark brown
G-9	Tan	Light brown	Mahogany	Mahogany
G-11	Tan	Light brown	Brown	Mahogany
I-1	Mahogany	Mahogany	Black	Black
I-3	Brown	Mahogany	Mahogany	Dark brown
I-5	Light brown	Light brown	Mahogany	Mahogany
I-7	Tan	Light brown	Light brown	Mahogany
I-9	White	Tan	Tan	Brown
I-11	White	Tan	Tan	Brown
K-1	Brown	Brown	Brown	Brown
K-3	Light brown	Light brown	Light brown	Light brown

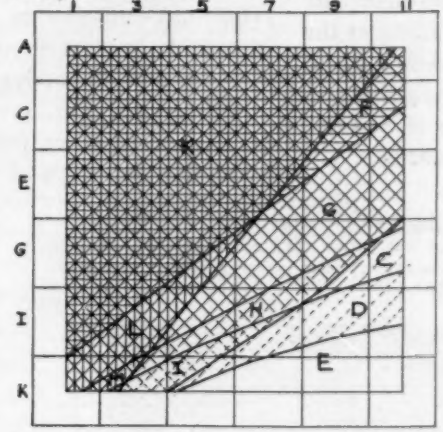
K-5	Tan	Tan	Tan	Tan
K-7	White	White	White	White
K-9	White	White	White	White
K-11	White	White	White	White

The color of the glazes obtained upon clays, containing varying iron oxide, silica, and alumina contents may be expressed in the following equation in which C is the color factor of the glazes and varies in proportion to the darkness of color. When C is between 0 and 2.0 per cent, the clay will take white to tan glazes; when this falls within 2.0 and 3.5, it will produce light brown colors; when between 3.5 and 4.75 it will produce brown glazes; when between 4.7 and 8.2 it will produce mahogany colors, and when over 8.2 it will produce dark brown to black glazes.

$$c_1x_1 + c_2x_2 + c_3x_3 = 100C \quad (3)$$

x_1, x_2 and x_3 represent the percentages of alumina, silica, and iron oxide, respectively, in the clay in terms of calcined weight. c_1 and c_2 represent the color factors which were found to be +10.30 and −2.65 for alumina and silica, respectively. The color factor for iron oxide, c_3, varies from 68.7 to 244.0 depending upon the salt glazing temperature, see Figure 5.

Figure 3.
The color and gloss of salt glazes obtained at cone 7 on clays of varying silica, alumina and iron oxide contents.



The value, c_3, may be approximately calculated from the following empirical formula for different temperatures:

$$c_3 = 14.6 + 54.1\ (1.0066)^{(T-1110)} \quad (4)$$

T is the salt glazing temperature in degrees Centigrade.

c_3 may also be obtained by referring to the curve for iron oxide in Figure 5.

The calculated and the observed values for c_3 are given in the following table:

Temperature, °C.	Observed values for c_3	Calculated values for c_3
1110	68.7	68.7
1190	106.0	106.0
1270	165.0	169.0
1330	244.0	244.0

The darkening effect of iron compounds upon the color of sewer pipe glazes is probably due to the transition of ferric compounds to ferrous compounds which takes place readily at high temperatures. Ferric silicates give red colors to glazes while ferrous silicates as a rule produce black colors.

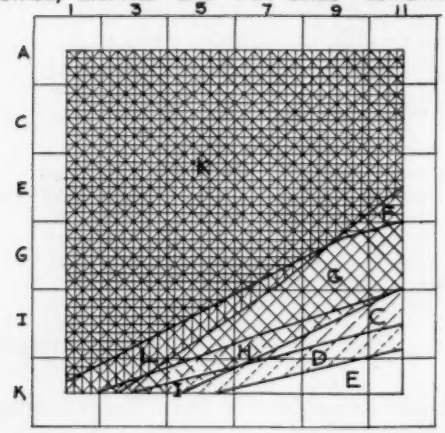
Varying the Salt Glazing Temperatures and Composition of the Body as Means of Improving the Quality of Sewer Pipe Glazes

Clays containing a high iron oxide content should be fired and salt glazed at as low temperatures as possible in order to produce glazes having the best color and smoothness, while clays having a low iron oxide content should be salt glazed at higher temperatures to produce the dark colors.

The writer has previously shown[1] that the brightness of sewer pipe glazes can be increased by adding fine silica to a clay.

Figure 4

The color and gloss of salt glazes obtained at cone 10 on clays of varying silica, alumina and iron oxide contents.



C-Brown Bright. G-Mahogany Semi Matt.
D-Light Brown Bright. H-Brown Semi Matt.
E-White to Tan Bright. I-Light Brown Semi Matt.
F-Dark Brown to Black Semi Matt. K-Dark Brown to Black Matt.
L-Mahogany Matt.

The results of this work indicate that decreasing the iron oxide content will also greatly improve the brightness and smoothness of salt glazes. For example reducing the iron oxide content 1.00% is equivalent in its effect upon the brightness of glazes to the addition of 6.1% silica when glazed at cone 02, to the addition of 7.8% silica when glazed at cone 3, to the addition of 12.6% silica when glazed at cone 7, and to the addition of 20.8% silica when glazed at cone 10.

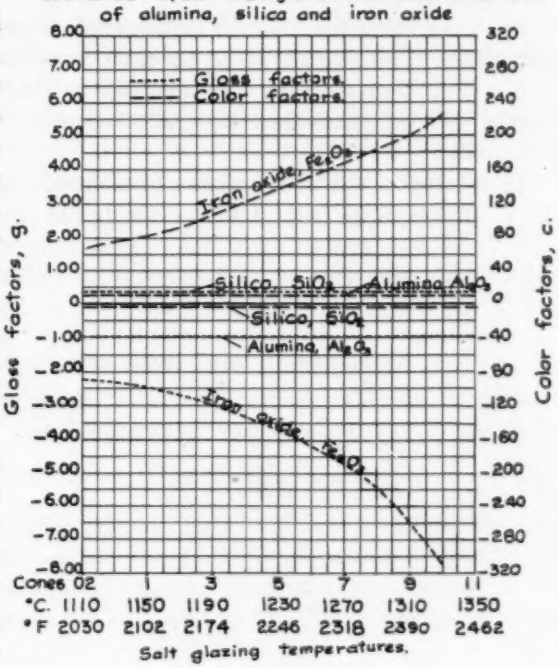
[1] The effect of variable alumina, silica and iron oxide in clays on some properties of salt glazes, *loc. cit.*

Decreasing the alumina content one per cent is equivalent to increasing the silica content 2.7%. This relation does not change much with an increase in temperature as is the case with iron oxide, but remains practically constant for temperatures between cone 02 and cone 10.

Summary and Conclusions

Since these tests were conducted in commercial kilns, the results apply fairly accurately when the ware is fired and salt glazed in commercial kilns under normal conditions. These results also apply more particularly to clays composed chiefly of alumina, silica, and iron oxide, the other impurities totalling to less than 1.00%. If the kiln is fired extremely reducing the glazes obtained would be similar to those obtained at high temperatures. If fired strongly oxidizing the results would approach those obtained at lower temperatures.

Figure 5.
The influence of different salt glazing temperatures upon the gloss and color factors of alumina, silica and iron oxide



1. Increasing the salt glazing temperatures causes those clays containing iron oxide to take duller glazes. The effects of varying salt glazing temperatures upon the brightness of salt glazes may be determined by calculating the gloss factor G in the following equation. When G is greater than 0, the glaze will be bright, when between -0.1337 and 0 it will be semi matt and when below -0.1337 it will be matt.

$$-1.00x_1 + 0.376x_2 - (1.885 + 0.385\ (1.01253)^{(T-1110)})x_3 = 100G$$

2. Increasing the salt glazing temperatures darkens the glazes obtained on clays containing iron oxide.

The color of the glazes may be obtained by calculating C in the following equation. C varies in proportion with the darkness of the color.

If between 0 and 2.00 white to tan colors will be produced; if between 2.00 and 3.5 light brown colors will be obtained; if between 3.5 and 4.75 brown colors will be produced; if between 4.75 and 8.2 mahogany colors will be obtained; and if above 8.2 dark brown to black colors will be obtained.

$$10.3x_1 - 2.65x_2 + (14.6 + 54.1\ (1.0066)^{(T-1110)})x_3 = 100C$$

3. Clays containing a high iron oxide content should be salt glazed at low temperatures, while clays having a low iron oxide content should be salt glazed at high temperatures to produce desirable glazes.

4. Decreasing the iron oxide contents will greatly improve the brightness of the salt glaze. This effect will be greater at higher temperatures than at low temperatures.

5. Decreasing the alumina content will improve the brightness of the salt glaze. This effect is about the same at all temperatures.

6. High alumina clays with a certain percentage of iron oxide produce darker colored glazes than high silica clays with the same percentage of iron oxide.

In conclusion the writer wishes to acknowledge his indebtedness to Dr. E. W. Tillotson for helpful advice during the progress of this work.

SOME UNAVOIDABLE HEAT LOSSES IN THE USE OF PERIODIC SYSTEMS[1]

By Robert H. Armstrong

ABSTRACT

This paper deals with an approximation of the heat lost: (1) In cooling ware from drier temperature to air temperature and the subsequent reheating. (2) In getting rid of moisture absorbed while ware is cooling and being set in kilns. (3) In a waste heat drier system. All heat values are summed up both for one single burn and over a year's time in tons of average coal representing these losses.

Introduction

The best kiln ever built lacks in efficiency. There are losses of heat in periodic kilns due to heating up of the cold kiln and the cooling of the hot one. In this article three different losses are approximated. Minor they may be, nevertheless they are important.

1. Loss due to cooling the ware from drier to air temperature and the subsequent reheating. 2. Loss due to moisture absorbed while the ware is cooling and being set in the kilns. 3. Loss of heat in a waste heat drier system.

To state in final terms of tons of coal wasted we shall use 12,546 B.t.u. per pound as the heat value of the average bituminous coal. This equals 25,092,000 B.t.u. per ton.

Due to Cooling from Drier Temperature

Coming from the drier at 250°F the brick are cooled to air temperature in order to be handled by the setters. This cooling loss is small but amounts to considerable in a year. Specific heat of the mass: $\left(\frac{H}{m(t_2-t_1)}\right)$ from which we get H equals $sm(t_2-t_1)$, where H is the heat developed in calories, m is the mass in grams, s the specific heat, and t the temperatures in °C. The "Clay Products Cyclopedia" gives the specific heat of clay as 0.23. The temperatures are 121° and 21°C. The average dry weight of a brick was found to be 2825 grams. With these values $H = 0.23 \times 2825 \times 100$ or 64,975 calories per brick lost in cooling. Since 252 gram-calories equal 1 B.t.u. this loss of heat is equivalent to 257.8 B.t.u. per brick. For each kiln of 132,000 bricks set, there is lost from this cause alone $132,000 \times 257.8$ B.t.u., or 34,029,600 B.t.u., a loss of 1.36 tons of coal on each burn.

Loss Due to Moisture Absorbed

Clay absorbs moisture as soon as it is exposed to the atmosphere and cooled down to air temperature. In order to determine just how much

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Heavy Clay Products Division).

moisture a brick gains while cooling and being set, two lots of ten brick each were accurately weighed as they came from the drier, then boxed in with other brick to get setting conditions and reweighed at intervals. The relative humidity and temperature of the air were taken at each weighing. Table I gives the results of one of these experiments. All weights are given in grams.

TABLE I

Brick No.	Dry weight	At 24 hrs. Weight	At 24 hrs. Gain	At 48 hrs. Weight	At 48 hrs. Gain	At 72 hours Weight	At 72 hours Gain
1	2706	2712	6	2714	8	2716	10
2	2725	2730	5	2731	6	2734	9
3	2746	2753	7	2755	9	2756	10
4	2742	2748	6	2750	8	2753	11
5	2778	2786	8	2787	9	2789	11
6	2747	2754	7	2754	7	2756	9
7	2760	2765	5	2766	6	2770	10
8	2788	2797	9	2797	9	2800	12
9	2812	2819	7	2822	10	2824	12
10	2849	2856	7	2857	8	2859	10
Average Gain		6.7 g.		8.0 g.		10.4 g.	
Per cent Gain		0.24%		0.29%		0.37%	

	Start	At 24 hrs.	At 48 hrs.	At 72 hrs.
Rel. Hum.	87	60	64	67
Temp. Air	52	48	37	50

Average dry weight of a brick 2773 grams or 6.1 pounds.

Our time for setting a kiln averages three days. To get the moisture gained during these thirty-six hours we take the mean between the twenty-four and forty-eight hour gains. This is 7.4 grams. With 132,000 bricks to a kiln this means 976,800 grams or 2152 pounds of water are absorbed. To evaporate this moisture at 70°F requires 1052 B.t.u. per pound or a total of 2,263,904 B.t.u. for each kiln or 0.09 tons of coal.

Loss of Heat in a Waste Heat Drier System

A kiln of brick just burned off contains heat energy which is largely wasted. The loss through radiation is immense. For nearly twenty-four hours after the conclusion of the burn, the stack dampers are open to rid the kiln of gases. This wastes considerable heat which if used for drying would scum the brick. The kiln walls, crown, flues and stacks contain a lot of usable heat. But in calculating only the actual drying value of the heat stored in 132,000 bricks at 960°C the following data are available.

The brick burned weighs 5.5 pounds or 2495 grams. One brick cooling from 960° to 21°C releases $.23 \times 2495$ grams $(960° - 21°)$ or 538,845 calories or 2138 B.t.u. One hundred and thirty-two thousand bricks release 282,216,000 B.t.u., an equivalent of 11.24 tons of coal.

A wet brick weighing 3082 grams has a drying loss of 257 grams of water. The evaporation of 257 grams or 0.566 pounds of water at 21 °C requires .566 × 1052 B.t.u. or 595 B.t.u. The heating up of a brick to drier temperature we found before to require 258 B.t.u. The total heat requirement per brick in the drier is 258 plus 595 or 853 B.t.u. A kiln of hot brick should then be capable of drying 330,850 bricks.

With eleven kilns a month available no kiln need be used for the drier more than three days. Even at this our drier temperature sometimes falls to 100 °F. If the drier is doing its best 45% of 11.24 tons or 5.06 tons of coal value are wasted per kiln unit.

If the sulphur compounds in the gases of the cooling kiln could be rendered inocuous as scum producer on the wet brick, it would make possible the use of much of this heat now wasted. Unfortunately, only the sulphates which do not decompose at this temperature are sodium and zinc but they are white. Such sulphates as manganous and ferrous sulphates which would add to the color of the ware will decompose. Cobaltous and vanadium sulphates could be formed at somewhat lower temperatures but the cost would be prohibitive.

Conclusions

We have found by very fair approximation that from these three minor sources alone, for each kiln unit of brick the losses are from:

		Tons
1.	Cooling brick from drier.....	1.36
2.	Moisture absorbed while cooling.....	.09
3.	Heat lost in drier system at its best....	5.06
	Kiln total	6.51

One hundred and thirty-two kilns of brick are burned off on the average in a year. The losses give in a year:

1.....	179.52 tons
2.....	11.88
3.....	667.92
Yearly total	859.32

In other words twelve and a quarter large cars of coal are bought in a year to produce this wasted heat, enough to have burned thirteen or fourteen more kilns.

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Discussion

MR. THWING: In allowing it to cool down to room temperature and then starting over again and heating it up to burning do you not lose that heat only once?

MR. ARMSTRONG: If you are using a continuous kiln your brick runs straight from the drier into the continuous kiln and you have that much heat in the brick going into the tunnel kiln which does not have to be regained whereas if it was cooled down that many degrees when it went into the kiln it would have to be reheated and the same amount of heat would have to be put back in.

MR. ARMSTRONG:[1] It does not make such a great change in the net loss since it only halves a small loss. Concerning the inability of what heat we have available from our kilns being sufficient for drying the brick at all times, I would say that this is due to two main causes. (1) The inability to reserve the heat when not needed for future use when no hot kiln is available. (2) The lack of flexibility in our drier equipment which is able to take care of perfect drying only when the air enters and leaves at certain temperatures and at a certain humidity. As the drier heat falls we have no way of proportionately increasing the speed of the air through the drier and no control over humidity. The nearest approach to perfection, that I have seen, of a waste heat drier is on a plant where all the kiln gases during both burning and cooling are pulled through the drier in 10-inch cast iron pipes by means of a fan and regulated by a damper which shunts any part of this heat out of an outside stack. In any such drying system the plant production must be nearly constant to insure proper drying at all times. In the latter system one great drawback is that the pipes become scaled with sulphur and lime compounds and this must be removed with steam injection.

MR. JACKSON: Mr. Armstrong mentioned casually about ferrous sulphate being used as a possible source of taking up sulphur. In the course of laboratory experiments I found that ferrous sulphate is decomposed in air. I have mixed ferrous sulphate with a pure Georgia clay and it decomposed beginning at around 500°C. It decomposes particularly in a neutral or reducing atmosphere. The decomposition is pretty nearly complete before 800°C is reached. Strangely enough if you heat a mixture of ferrous sulphate and clay in an atmosphere of pure oxygen, heating it up to practically finishing temperature of the kiln, you only get 29% of the sulphur given off.

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[1] Recd. April, 1924.

THE OXIDATION OF CERAMIC WARES DURING FIRING.—III. THE BEHAVIOR OF CALCIUM COMPOUNDS IN CLAYS[1]

By Frederick G. Jackson[2]

ABSTRACT

Previous theories on the formation and decomposition of calcium sulphate as kiln scum are confirmed. Quantitative analyses on the effect of definite heat treatments put the subject on a more definite basis.

Introduction

Calcium compounds occur in practically all clays and may be present in amounts varying from a fraction up to 30%[3] in commercial clays. The two most common compounds of calcium existing with clay are the carbonate (limestone) and the sulphate (gypsum).

Gypsum is slightly soluble in water, about one part in 500, and consequently may be deposited with a clay by evaporation or washed out by a natural lixiviation. It may be absent from the clay, but present in the pug water. Many scumming troubles have been solved by a change to "soft" water. When the ware is dried, the water evaporating deposits white crystals on the surface of the ware producing the familiar drier scum.

A similar scum, however, can be formed in a kiln in the absence of calcium sulphate in the dried ware. An explanation of this is the purpose of this paper.[4]

Calcium Sulphate Scumming in Kiln

Conditions may be such that calcium sulphate is formed in the kiln from the carbonate. The necessary factors are calcium carbonate, sulphur trioxide, and plenty of water to dissolve it.

The drying can never be complete even for the mechanically combined water, and there is up to 10% of chemically combined water, which is only liberated around 400°C. The top of the kiln heats more rapidly than the bottom. If the draft is not strong the water from the top courses will accumulate in the lower courses and will persist until the top courses get to a dull red heat. At this stage kiln scum is inevitable if limestone is present, due to conversion of the calcium carbonate to calcium sulphate by the sulphur trioxide from the coal gases.

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[1] Published by permission of the Director, U. S. Bureau of Mines.

[2] Associate Chemist, Columbus Station, U. S. Bureau of Mines.

[3] See Seger, "Collected Writings," 1, 435.

[4] For a popular treatment of this subject without quantitative data, see a series of papers by Ellis Lovejoy in *The Clayworker* for 1906–7. These have been combined in pamphlet form under the title "Scumming and Efflorescence" and published by F. J. Heer, Columbus, Ohio.

Cause of Kiln Scum A laboratory experiment has shown this very clearly. Two bars were made of 14 parts by weight of plastic kaolin[1] and one part of calcium carbonate; also one bar of 14 parts Bedford shale and one of calcium carbonate. One of the kaolin bars was thoroughly dried at 110°C. One kaolin bar and the bar of shale were in a plastic state when all three were put into a glass tube. This tube was connected, through a drying tube, with a combustion furnace. In the combustion tube was a bar of clay containing five grams of $Fe_2(SO_4)_3$. This was heated, evolving SO_2 and SO_3. Gentle suction drew these gases first through the drying tube, then over the dry kaolin bar and then over the wet bars. The bars all had, therefore, an equal chance to absorb sulphur gases. Each bar was then extracted by boiling with successive lots of 500 cc. of distilled water until the filtered extract gave no test for sulphate. They showed the following contents of sulphur trioxide. The equivalent amount of calcium carbonate is also given:

	SO_3 gms.	Equivalent $CaCO_3$%
Pure kaolin dry.....	0.0170	2.12
Pure kaolin wet.....	0.0940	11.76
Bedford shale wet.....	0.0750	9.96

All tests showed the absence of calcium sulphite and sulphide.

This shows that when ware is properly dry there will be little sulphate formation from conversion of calcium carbonate during watersmoking. If the ware is wet, exactly similar conditions will give 10–12% conversion.

Elimination of Kiln Scum That calcium sulphate once formed in ware can be removed is known.[2] In an oxidizing atmosphere, it decomposes only at very high temperatures, but under reducing conditions, it is more easily broken down. A. E. Williams[3] made good black flashed brick from scummy and poor flashing clays by spraying the surface with $FeCl_3$ solution as the clay column came through the die.

Williams also experimented[4] on the reduction of calcium sulphate. With a mixture of 20% gypsum and 80% clay heated in a combustion tube in an atmosphere of pure CO, for two hours at 800°C, he found complete reduction; also with an atmosphere of 44% CO_2, 35% CO, and 2% O_2. With the latter atmosphere for two hours at 750°, he found only slight reduction, and at 700° for two hours no reduction; for three hours a slight reduction.

[1] For analysis of this see *Jour. Amer. Ceram. Soc.*, **7** [4], 224(1924).

[2] See Seger, "Collected Writings," **1**, 148; also Garve, *Trans. Amer. Ceram. Soc.*, **17**, 600(1915).

[3] *Trans. Amer. Ceram. Soc.*, **17**, 764(1915).

[4] *Ibid.*, **18**, 271(1916).

We have investigated this subject from a quantitative standpoint. A number of bars were prepared of 15 grams of plastic kaolin and one gram of celenite ($CaSO_4.2H_2O$) ground intimately together, tempered with distilled water, molded by hand, and dried at 110°. A bar was then put into a combustion tube, heated to the desired temperature and held for an hour with natural gas passing over it. The furnace was then thoroughly cooled with the gas still passing. When cold, the bar was removed and ground fine. It was then extracted by boiling with successive lots of 500 cc. each of distilled water, boiling each for half an hour. The filtrates were analyzed[1] for SO_3 and SO_2 until extraction was complete.

Evidence pointed to the probability of there being much more sulphide than sulphite. However, sulphide and sulphite would behave alike in reoxidizing to sulphate and they are, therefore, combined in the analysis.[2]

Temperature	700°C	750°C	800°C	850°C
$CaSO_4$ remaining, %	85.22	31.04	9.92	4.20
$CaSO_3$ or CaS formed, %	14.07	46.87	39.14	39.10
CaO by difference, %	0.71	22.09	50.94	56.70

From these results it would appear possible to remove a large amount of drier scum or kiln white from scummed ware by maintaining a reducing condition in the neighborhood of 800–850°, and following this by oxidation.

CERAMIC EXPERIMENT STATION
U. S. BUREAU OF MINES
COLUMBUS, OHIO

[1] For a description of the method of analysis, see *Jour. Amer. Ceram. Soc.*, **7** [3], 169(1924).

[2] The method of this combined analysis is discussed in *Jour. Amer. Ceram. Soc.*, **7**, 228(1924).

PLASTICITY AS A MEANS FOR CONTROL OF PROPERTIES[1]

By Eugene C. Bingham

Perhaps in no field is the property of plasticity more important than in the ceramic industry and the nature of plasticity has been better understood in this industry than in any other. But the early efforts to measure it directly seem to have failed very largely for the measurements of plasticity given in the literature have been largely indirect in nature based on shrinkage on drying or burning, tensile strength or adsorption of malachite green, etc. The records of the flow of clay slip were very scanty presumably due to the difficulty in obtaining data which were reliable indications of the property.

There is every advantage in having a variety of indirect methods for measuring the property in question, but indirect methods have their greatest value only when direct methods are available for the exact measurement of the property. This principle is particularly well illustrated in the case of plasticity. It is now known that the viscosity of a colloid, such as clay slip, is not a constant but varies with the shearing stress applied, so viscosity measurements as such mean very little. If the rate of deformation is plotted against the shearing stress a pure liquid gives a linear curve passing through the origin as *OA* in Fig. 1. But a plastic substance gives a curve *BC*. A certain shearing stress *OB*, the yield value, is required to start the flow but after the flow is started the increase in shearing stress increases the flow just as in true liquids, the result being that a plastic material may yield little if any as pressure is first applied but when a certain pressure is exceeded it yields rapidly. The property analogous to the fluidity of liquids is called *mobility* and the property analogous to viscosity is probably *consistency*.

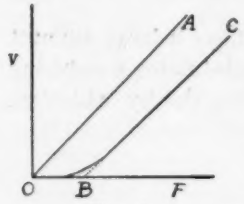

Fig. 1.

Just as metals below their elastic limit are known to yield very slightly, so plastic materials in general yield somewhat before the yield point is reached. Thus the curve *BC* bends off toward the origin at low shearing stresses.

This much seems to be established by the very incomplete researches which have been carried out thus far on the subject of viscous and plastic flow. And this is enough to show that no single property such as tensile strength, adsorption of dye or shrinkage can possibly be a measure of plasticity, for plasticity is a complex property made of two properties which are mutually independent. One of these properties may be an exact measure of the yield value *or* of the mobility but not of *both* at the same time.

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Whitewares Division).

We arrive, therefore, at the conclusion that in order to control the plasticity of clay we must obtain knowledge of the factors which affect the yield value and mobility.

Other properties which depend on the flow of solids such as hardness, malleability, ductility are also complex properties which probably may be quantitatively defined and measured in terms of yield value, mobility and so forth. It can even be shown that in emulsion colloids the terms melting-point and solubility as well as viscosity are vague in their meaning, but that through a knowledge of plastic flow it is possible to give these properties a meaning analogous at least to that which they have in classical chemistry. It would be out of place here to go into details of that subject.

It may, however, be not inappropriate to outline here how control properties of value may be expected to result even in colloidal suspensions such as clay or paint. Paint has offered an attractive subject for investigation because the dispersion medium may be made non-volatile. It has been found that the mobility rapidly lowers as the concentration increases and in a linear manner so that if one knows the fluidity of the medium and the mobility of one mixture, it would be possible to calculate the mobility of any mixture whatever. There is a definite mixture at which the mobility would become zero and this is evidently connected with the close packing of the clay or paint.

The yield value-concentration curve is also linear over a certain range, the yield value increasing rapidly as the concentration is increased. By extrapolation there is a certain concentration at which the yield value would be expected to be zero. This concentration is presumably dependent upon the size of the particles but particularly upon the adhesion between the particles. Thus a paint ground in mineral oil showed a loss of 81% in its yield value of 1090 when only 0.2 per cent of oleic acid was added, without affecting the mobility. The addition of very small amounts of various classes of substances are of very great importance. Thus the addition of a soap (aluminum stearate) to a paint was found to decrease the mobility only slightly (12%) whereas the yield value was raised nearly 800%. As another proof of the great effect of small additions, 0.5% of moisture raised the yield value of a paint 3700%. In a similar way we might expect small quantities of an oil or colloid to greatly affect the yield value of a clay slip. It has already been shown that the effect of small amounts of acid exert a prodigious effect on the yield value.

The effect of temperature is to raise the mobility in the same ratio as the temperature raises the fluidity of the medium. But the temperature has no effect on the yield value. It is inferred that other causes which brought about an increase in the fluidity of the medium would also increase the mobility without necessarily affecting the yield value.

With such prodigious effects upon first the yield value and then upon the mobility or sometimes on both, we may safely assume that a knowledge of these properties will permit better control in the ceramic industry and it will disclose the means for obtaining properties in clay which are desired but which are now somewhat mysterious. Given two new properties of a fundamental nature which can be quantitatively measured it seems useless to ask whether they may be of use. What is needed is much more work carried out in close coöperation with the industries.

The university offers a suitable place for the investigation of the methods of measurement, of the basic laws and theories of flow. The industries have an enormous fund of practical knowledge of what is wanted even where the reason why cannot be assigned. The happy union of these two forces ought to result in the progress of American industry and in the broadening of the theoretical foundation of the Science of Colloid Chemistry.

LAFAYETTE COLLEGE
EASTON, PA.

Discussion

DR. SCHRAMM: As I understand it, Dr. Bingham's work on plasticity has been on slips. He has referred to paint slips and to clay slips. If he would translate the work into the determination on the properties of clay in the plastic condition so that the properties which determine the actual plasticity of clay as it is worked, may be determined, the method would be of a real practical value to the potters.

DR. BINGHAM: Our first work on clay slips was in 1916. As I understand you, what is really wanted is a correlation between the properties as we measure them in the clay slip which has a high percentage of water with the properties which are in the plastic clay as it is actually cast.

DR. SCHRAMM: That is right.

DR. BINGHAM: It seems to me that there is a gap right there, which needs to be filled in by further investigation.

DR. SCHRAMM: Is there a possibility of making these measurements in the plastic clay directly?

DR. BINGHAM: It seems to me that is where it *should* be done and there ought not to be any experimental difficulty unless the particles are of an extremely great size so that they would clog up the tubes that are used.

It is advantageous, in measuring plasticity, to use small tubes of considerable length. We have had very good results in working with materials like the dental impression compounds which are used to get the impression of the mouth. They contain varnish gum, stearic acid and perhaps talc mixed together, and the amount of flow which one gets through the plastometer with any degree of pressure is very small, and yet it gives very interesting and helpful results.

MR. MCAFEE: It seems to be impossible to base calculations exactly on the clay taken in any unit. For instance the moisture content will vary considerably between the pieces lying side by side in the clay bin. Methods of taking samples tend to give average results but this is not exact. It also does not seem possible to determine by exact scientific means whether or not a clay slip is just right for casting. Determinations of viscosity and specific gravity do not tell the whole story. Different samples of the same clay shipment give different results when used in the same formula.

PROF. SHAW: I have been trying to decide whether we were discussing here the subject of viscosity or plasticity, and whether there is a distinction. I have not thought plasticity and viscosity were the same. Definitely, what is plasticity?

DR. BINGHAM: To my mind plasticity always refers to a substance which can be readily molded or shaped under a convenient shearing stress, but which will hold its shape when the shearing stress is removed. Pitch is not a plastic solid, because it does not hold its shape. Quartz is not plastic either under ordinary conditions, but for a different reason, *viz.*, because it cannot be molded. There are then two distinct properties involved in the notion of plasticity. The one is the shearing stress required to continuously deform the material which is called the yield value; the second, dependent upon the amount of deformation in a unit cube of the material when the yield value has been exceeded by a definite amount, which is called the mobility.

The reason why a single property, *viz.*, the viscosity, will define the flow properties of a fluid whereas two properties—yield value and mobility—are required to define the plasticity of a solid can best be understood by the use of simple diagram, Fig. 1. It is seen that the volume of flow in a viscous liquid varies directly as the shearing stress, so that deformation takes place at any shearing stress no matter how small and the fluidity is fully determined by one observation. On the other hand, in plastic solids continuous deformation does not take place except when the shearing stress exceeds the yield value *f* and two determinations are necessary in order to determine the flow characteristics of the material.

DR. SCHRAMM: Could you say that one substance had greater plasticity than another?

DR. BINGHAM: It would be strictly incorrect to speak of one substance as having greater plasticity than another unless it is tacitly assumed that one or the other of the two independent variables is kept constant. For example, it appears that in making up paints the effort of the manufacturer is to keep constant that property which we know as yield value. We can see why this is so, because every paint should have sufficient yield value to remain in place on the surface to which it is applied, but it should not consume an unnecessary amount of energy in the process of

application. If then all paints of painting consistency have the same yield value, it would be natural to speak of those paints which have the highest mobilities as the most plastic. Conversely, if in some industries the material used is always made up to a fixed mobility, we can imagine their referring to those substances which have the highest yield values as the most plastic. But whenever plasticity is to be stated quantitatively, it should be done in terms of yield value and mobility. Good plasticity seems to be dependent upon a high yield value and a high mobility.

DR. SCHRAMM: It is very hard to avoid talking about plasticity. We are constantly using the term to indicate what we might call the working properties in clays. If we are to be deprived of the word plasticity, somebody will have to give us another one.

DR. BINGHAM: I think the term plasticity should retain its loose meaning. Ceramists state that a certain clay has good plasticity but they do not mean the same thing that metallurgists mean when stating that zinc is plastic. Still different ideas of plasticity are in mind when one is handling rubber, lime, or nitrocellulose. Each industry needs a certain combination of yield value, mobility and perhaps certain other properties such as elasticity. We can speak perhaps of an *optimum* plasticity for each industry or industrial operation when the yield value and mobility are within certain limits.

DR. SCHRAMM: Might it not be possible to determine a single factor which would describe the workability of clay without dissecting it in this way?

DR. BINGHAM: We can state that a given material has a satisfactory plasticity or workability, but we apparently cannot avoid having to deal with at least two independent variables. Even the painter in his test of plasticity does two things which may test the two variables in question. He stirs the paint carefully observing the resistance to the paddle, which apparently gives an indication of the mobility. He then lifts the paddle up and notices how the paint streams from the paddle and from this we may assume that he gathers some idea of the yield value. It does not seem to me likely that we shall be able to represent the plasticity by any complex factor such as the product of the yield value times the mobility. The reason for this is that the yield value must lie within certain prescribed limits and any passage of these limits in either direction cannot be made up except in a limited degree by adjusting the mobility. I think that it will be readily believed that many clays may be given a prescribed yield value or mobility, by the addition of water in varying quantities, but both of these properties cannot be adjusted at a predetermined value at the same time, so we have plastic and non-plastic clays.

QUESTION: How is the shearing stress applied?

DR. BINGHAM: There are a number of ways in which this may be done. With very soft solids we have found it most convenient to force the material through capillary tubes under a measured pressure. The material flowing from the capillary in a given time is then measured in a variety of ways.

PROF. SHAW: Professor Orton distinguished between the plasticity of an asphalt and a material of the character of clay. As I remember it, he termed the plasticity of an asphalt as pseudo-plasticity as distinguished from that of a clay which is normal plasticity. The basis of his distinction being that the plasticity of the asphalt results from mixing a non-plastic powder with a *viscous* liquid, while the plasticity of the clay is characteristic of the powder itself.

Many different methods have been proposed by members of this SOCIETY for measuring viscosity. The viscosimeter which measures the quantity of material which flows through a capillary tube is an exact duplicate of what has been described here, except that with that instrument your pressure is simply gravity. Here you are doing precisely the same thing, only you have a high viscosity and are compelled to use a higher pressure to force it through there.

In order to avoid that, Bleininger and a little later, I, myself devised a little different type of viscosimeter in which we used a larger tube. We still used the gravity pressure and measured the viscosity of our material by measuring the quantity of material which flowed in a given time.

In the viscosimeter which I devised, in testing the viscosity of enamels which would not flow through a small capillary tube, I had two tubes—a single cylinder with a $^{5}/_{32}$-inch tube on one side and a $^{3}/_{32}$-inch tube on the other, both opening into the same cylinder. I let the material flow through both tubes at the same time, measuring the quantity which flowed through each of the tubes.

We are still dealing with viscosity. We are not dealing with *plasticity*, but rather with simply one of the factors which influences plasticity.

Emley has devised a plasticimeter which he contends measures the plasticity of clay, but as I see it what he does is the same thing as has been done here—he measures the resistance of the clay to the flow. There are a number of different factors which enter here. The friction between the tubes and the material is one factor, and the cohesion between the particles themselves is another factor. There is a complication there which influences the measure of the result and which no instrument yet devised has been able to eliminate. It is a well-known fact that clays of high viscosity are not necessarily highly plastic. On the other hand some mixtures do exhibit plasticity in direct proportion to their viscosity.

I have simply gone into this to repeat what I said awhile ago that this term plasticity covers a number of things in the mind of the ceramic

man, and we do not know what we are talking about when we use the term plasticity. The term is described in our ceramic writings as being that property of clay which makes it capable of being molded and of retaining its form until it is changed by the application of some exterior force. That is a definition which has sufficed to date for us, but it is quite meaningless and all efforts spent on trying to reduce it to concrete terms are worthy of commendation. This work of Dr. Bingham's surely falls into that category and I am sure we all wish him success in the pursuit of the subject.

A MEMBER: Dr. J. W. Mellor[1] describes a method of determining the two factors of plasticity on plastic clay. A sphere of clay is compressed by the application of a gradually increasing load until cracks develop. The amount of movement gives the deformability (corresponding to Dr. Bingham's mobility) and the load divided by the distance moved gives the resistance (corresponding to the yield value). A plasticity number is expressed as the product of the two, although Mellor recognizes a qualitative difference in clays according to the magnitude of the two factors. It would appear that the method described by Mellor is correct in principle but experimentally uncertain as the small spheres (only 2 cm. in diameter) are not easy to make. With improvement in technique this method should give a satisfactory basis on which to measure the working qualities of clay.

PROF. WATTS: To me "plasticity" is a combination of viscosity, lubrication value and bonding strength. But I believe that the general opinion holds that the peculiar and specific properties of ball clays are combined in two particular properties, greasiness or lubrication, and stickiness or bonding strength. If every man who has used ball clay would carefully analyze the way ball clay acts when he incorporates it in his body, he will recognize the fact that he is trying to acquire those two properties, greasiness or lubrication and stickiness or bonding strength. In this way, the mass containing ball clay is caused to mold with increased smoothness and the strength in the plastic state and the drying state are both increased.

However, in order to be able to do anything with these values, I have found that it has been necessary to dilute the ball clays, but I have not been satisfied with dilution of ball clays with water, and am now attempting to dilute them with a solid material, using finely pulverized flint in order to reduce the evidence of these properties to a sufficient degree so that I can get some value expression.

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[1] *Trans. Eng. Ceram. Soc.*, **21**, 91–103(1921-2).

A GRAPHICAL CHART FOR DETERMINING EXCESS AIR IN THE COMBUSTION OF PRODUCER GAS[1]

By Gordon M. Peltz

ABSTRACT

This paper presents a mathematical analysis of the combustion of the principal components of producer gas. Formulae are obtained for determining the theoretically right proportions of air to gas for any analysis of producer gas and the theoretical volume of waste gases which should result from this combustion. In addition, a formula is determined by which the percentage of excess air can be obtained when the analysis of the gas and the percentage of CO_2 in the products of combustion are known. These formulae are presented in a chart form which eliminates the necessity for mathematical calculations.

The purpose of this paper is to present a calculating chart[2] by which it is possible to determine the percentage of excess air existing in any producer gas fired furnace when the analysis of the gas and the percentage of CO_2 in the products of combustion are known.

Excess air is a very important factor, not only from the standpoint of fuel economy, but also in cases where the nature of the furnace atmosphere has an effect upon the operation involved. In spite of this, furnace operators rarely make determinations of the excess air, due largely to reluctance to take the time and trouble to make the necessary calculations as a regular daily routine. The desire to make a daily study of this question in a practical way led the writer to reduce the whole calculation to chart form.

This chart has saved valuable time and has made practical a daily study of the excess air conditions in furnaces. Hoping that the same may prove valuable to others, the chart and its derivation are herewith presented.

For furnaces using an unchanging fuel such as natural gas, coal or oil it is a comparatively simple thing to calculate the excess air represented by any given percentage of CO_2 in the flue gas. Having once made such a calculation a table can be made by which the percentage of excess air could be read directly from the percentage of CO_2. However, in considering producer-gas furnaces it is necessary to take into consideration the continually varying composition of the gas being used. The combustion of producer gas is in fact a two-stage combustion of coal but when so considered there is no way of determining the relative merits of the producer operation and the furnace operation. To properly judge the combustion of the furnace alone, apart from the producer supplying it, it is necessary to analyze the gas received by the furnace and the products of combustion delivered by it to the stack.

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[1] Presented at the Atlantic City Meeting, Feb., 1924 (Glass Division).

[2] Full size copies of this chart can be obtained by anybody by communicating with the author % Corning Glass Works, Corning, N. Y.

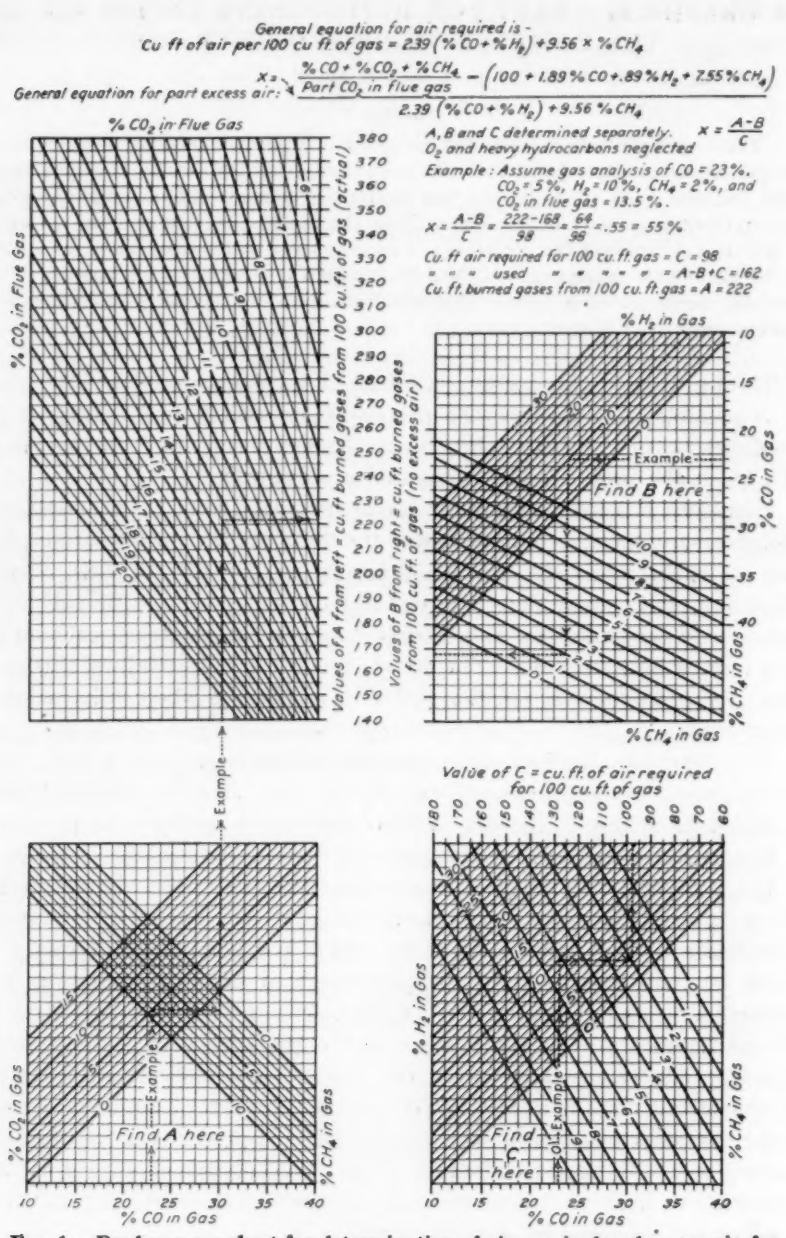
General equation for air required is -
Cu ft of air per 100 cu ft. of gas = 2.39 (% CO + % H2) + 9.56 × % CH4
General equation for part excess air: X = [% CO + % CO2 + % CH4 / Part CO2 in flue gas − (100 + 1.89 % CO + .89 % H2 + 7.55 % CH4)] / [2.39 (% CO + % H2) + 9.56 % CH4]
A, B and C determined separately. X = A−B / C
O2 and heavy hydrocarbons neglected
Example: Assume gas analysis of CO = 23%, CO2 = 5%, H2 = 10%, CH4 = 2%, and CO2 in flue gas = 13.5%.
X = A−B / C = 222−168 / 98 = 64 / 98 = .55 = 55%
Cu. ft air required for 100 cu. ft. gas = C = 98
" " " used " " " " = A−B+C = 162
Cu. ft. burned gases from 100 cu. ft. gas = A = 222
% CO2 in Flue Gas
Values of A from left = cu. ft. burned gases from 100 cu. ft. of gas (actual)
Values of B from right = cu. ft. burned gases from 100 cu. ft. of gas (no excess air)
% H2 in Gas
% CO in Gas
% CH4 in Gas
Example
Find B here
Value of C = cu. ft. of air required for 100 cu. ft. of gas
% CO2 in Gas
Find A here
Find C here

FIG. 1.—Producer gas chart for determination of air required and excess air, for any gas with any per cent CO_2 in flue gas. Also actual and theoretical volume of burned gases from combustion of 100 cu. ft. of gas.

Any producer gas can be considered as a mixture of CO_2, O_2, CO, H_2, CH_4, N_2, and some miscellaneous hydrocarbons of complex form which exist in the form of tar vapors. These latter are a small proportion of the total combustible and are of such variety as to be almost impossible to analyze and base calculations upon. They are therefore neglected in the following discussion. As the per cent of O_2 is always very small being usually less than one-half of one per cent, its effect is also neglected. For practical consideration, therefore, the gas is treated as a mixture of the combustible gases CO, H_2, CH_4, and the inert gases, CO_2 and N_2.

For the combustion of any fuel there is a definite quantity of air theoretically required to complete the combustion. This quantity will hereafter be spoken of as C. If any air in addition to that required is permitted to enter the furnace chamber, this air will pass through the furnace as an inert gas taking no part in the chemical reaction and will appear in the products of combustion as nitrogen and oxygen. In discussing the amount of this extra air it is customary to express it as a proportion of the amount of air theoretically required. Writing this in the form of an equation, we have

$$\text{Part excess air in flue gas} = \frac{\text{Vol. of excess air}}{\text{Vol. of required air, or } C}$$

From this it is apparent that we must find a method of determining the volume of extra air in the waste gas and also the volume of air required for a given volume of the fuel to be burned. The volume of extra air will be the actual volume of waste gases minus the theoretical volume of waste gases which would have been obtained under perfect conditions without excess air, that is

Vol. of excess air = Actual vol. of waste gas minus Theoretical vol. of waste gases for perfect combustion

For simplicity this is expressed as: Vol. of ex. air $= A - B$.

$$\text{Therefore, per cent excess air} = 100 \times \frac{A-B}{C}.$$

It is evident that the part or fraction of CO_2 in the waste gases =

$$\frac{\text{Vol. of } CO_2 \text{ in waste gas}}{\text{Actual vol. of waste gas, or } A}$$

Transposing this equation we have a means for finding the actual volume of waste gases for

$$A = \frac{\text{Vol. } CO_2 \text{ in waste gas}}{\text{Part } CO_2 \text{ in waste gas}}$$

The theoretical volume of waste gas which would result from perfect combustion, or B, can be calculated from the chemical composition of the fuel as can also the theoretical amount of air required, or C.

The chemical formulae for the combustion of the gases involved are as follows:

$$2CO + O_2 = 2CO_2$$
$$2H_2 + O_2 = 2H_2O$$
$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

Expressing these equations in terms of air required for the combustion of one cubic foot of each of the gases we have:

1 cubic foot of	+ cu. ft. air	Burns to cu. ft. CO_2	+ lbs. of H_2O	+ cu. ft. of N_2
CO	2.39	1	0	1.89
H_2	2.39	0	0.0501	1.89
CH_4	9.56	1	0.101	7.55

Adding these equations for the combustion of 100 cubic feet of any producer gas, keeping in mind the fact that the H_2O is lost by condensation in collecting sample we have the following:

Vol. air required for 100 cu. ft. producer gas $= C = 2.39(\%\ CO + \%\ H_2) + 9.56\%\ CH_4$

and

Vol. waste gases for perfect combustion $= B = 2.89\%\ CO + 1.89\%\ H_2 + 8.55\%\ CH_4$ plus non-combustible portion of gas

As the original gas is composed of the non-combustible portions plus per cent $CO + H_2 + CH_4$ and the volume of this gas under consideration is 100 cubic feet we can convert the above equation to the following form:

$$B = 100 + 1.89\%\ CO + 0.89\%\ H_2 + 7.55\%\ CH_4$$

The volume of CO_2 in the products of combustion from 100 cubic feet of gas will be the CO_2 originally in the gas plus that formed by combustion, that is:

Vol. CO_2 in waste gases from 100 cu. ft. of gas $= \%\ CO_2 + \%\ CO + \%\ CH_4$

Substituting this in our former equation for A which is the total actual volume of waste gases, we get:

$$A = \frac{\%\ CO + \%\ CO_2 + \%\ CH_4}{\text{part } CO_2 \text{ in waste gases}}$$

We now have each of the three quantities expressed in terms of the per cent of the various combustibles in the fuel and the fraction of CO_2 in the products of combustion. Substituting these values in the equation for excess air given above, that is, per cent of excess air $= 100 \times \frac{A-B}{C}$

we have the following general equation for excess air in the combustion of any producer gas with any fraction of CO_2 in the waste gases:

$$\% \text{ of excess air} = 100 \times \frac{\dfrac{(\% \text{ CO} + \% \text{ CO}_2 + \% \text{ CH}_4)}{\text{part CO}_2 \text{ in flue gas}} - (100 + 1.89\% \text{ CO} + .89\% \text{ H}_2 + 7.55\% \text{ CH}_4}{2.39\ (\% \text{ CO} + \% \text{ H}_2) + 9.56\ \% \text{ CH}_4}$$

As will be noted, when mathematically expressed, the formula is by no means a simple one and so the chart was made to simplify its solution. The chart is divided into three major portions, each of which furnishes the value for one of the quantities, A, B and C considered above.

To find the value for A begin in the lower left hand corner with the proper percentage of CO, project vertically to the diagonal line representing the percentage of CO_2 in the producer gas and from here project horizontally to the diagonal line in the opposite direction representing the percentage of CH_4 in the gas. From this point project vertically to the series of radial lines in the upper left hand portion of the chart to the line representing the percentage of CO_2 in the flue gases. From this point project to the right and read the value of A, which is the actual volume of waste gases resulting from the combustion of 100 cubic feet of producer gas.

To find B start with the proper percentage of CO in the upper right hand portion of the chart, project to the line representing the percentage of H_2 and then down to the line representing percentage of CH_4. From here project horizontally and read the value of B, which is the theoretical volume of waste gases for perfect combustion. The difference between A and B is the actual volume of excess air used.

To find C start with the proper percentage of CO in the lower right hand portion of the chart, project upward to the proper H_2 line, then horizontally to the proper CH_4 line and from there vertically to read C, which is the volume of air required to burn 100 cubic feet of the gas in question.

With a little study of the system used in the chart and a little practice, it will be found that satisfactory results can be obtained in a very few minutes and with very little difficulty. If care is used, the results obtained from the chart will be as accurate as the gas analysis is likely to be, which is sufficient for all practical purposes.

Discussion

MR. CARTER: May I call attention to the fact that if any dependence is placed upon the amount of carbon dioxide in the escaping gases it will be necessary to consider that if sodium carbonate is used in the melt, the carbon dioxide carried by that sodium carbonate is likely to appear in the escaping gases, and the amount of it from that source will depend entirely upon the vigor of the reaction which is taking place at that time, so that

the mere presence of a given percentage of carbon dioxide in escaping gases will be an erroneous foundation on which to build a very elaborate calculation in regard to excess air.

MR. SMITH: The amount of carbon dioxide appearing in the flue gases that comes from the chemical reaction of the batch is so small for practical purposes that it cannot be detected.

MR. CARTER: It very largely depends on the nature of the batch and the way it is put in. In the furnace with which I am familiar we have a periodic arrangement, that is, the batch is charged, the reaction proceeds for a certain length of time and then the melted material is moved. Under those conditions the amount of carbon dioxide appearing in the flue gases at certain stages of the reaction is a very considerable proportion of the total. Cases have been known in which carbon dioxide from the sodium carbonate of the batch has caused the analysis of outgoing gases to show 10% more CO_2 than it would have done if none had been derived from that source.

CHAIRMAN: I can see that if the reaction is taking place almost at one time and then it is melted down, quite a bit may be given off at once, whereas if the fills are made at regular intervals and the samples taken all along the port side of the tank and an average taken, it might be very, very small.

G. M. PELTZ:[1] The point brought up by Mr. Carter is of interest and importance, not so much because of the magnitude of carbon dioxide which will be produced in most glass tanks, but because it brings up the importance of taking into account the practical conditions met with in a specific application of any general theory or calculation, such as that presented in my paper.

It should be noted that the purpose of my paper is to present only a simplified method of performing a mathematical calculation and I have not gone into the practical questions of obtaining the necessary gas samples and analyses. The chart, which was presented, applies to the general combustion of producer gases and was not intended exclusively for the glass business or any other business. It will, therefore, be necessary in considering its use under specific conditions to carefully consider what effect these conditions will have upon the results.

Replying specifically to the point raised by Mr. Carter I have made a rough calculation to determine approximately the magnitude of the carbon dioxide given off by a soft lime glass batch. Assuming a batch containing 22% sodium carbonate about 10% of the weight of this batch will be given off as carbon dioxide which, of course, mingles with the flue gases. Assuming a batch to cullet ratio of 1 to 1 it is apparent that the weight of CO_2 will be only 5% of the weight of the fill. Expressing this

[1] Rec'd March 31, 1924.

in volumes we find that each pound of fill will produce 0.4 cu. ft. of CO_2. If 1 lb. of coal in the form of producer gas is required to every pound of fill, this will represent approximately 70 cu. ft. of producer gas which will require at least an additional 70 cu. ft. of air and will burn to at least 120 cu. ft. of non-condensible waste gases. About 17 cu. ft. of this total will be CO_2. It is apparent, therefore, that the CO_2 given off by the batch is not likely to be more than one-half of 1% of the total volume of waste gases nor more than $2^1/_2$% of the total volume of carbon dioxide. There may be special cases, such as mentioned by Mr. Carter, which might depart considerably from the above rough calculations, but such cases would be rather exceptional and would have to be treated as such.

As mentioned above it has not been my intention in this paper to go at length into the questions of obtaining representative gas samples and analyses for this question has been covered in many other books and articles. It is obvious, of course, that the results obtained from my chart cannot be more accurate than the analyses. It has been my experience that great care must be used in taking proper samples and that the errors due to such causes as non-representative samples, leakage, absorption of CO_2 by water, incomplete absorption in the Orsat apparatus, etc., are likely to result in greater errors than will be produced by gases given off from the batch.

In regard to the question of obtaining proper samples each specific case must be considered separately, but I have found it desirable to observe the following general rules in taking samples from glass tanks:

(1) The sample should be taken from a part of the furnace which is under positive pressure so as to avoid all possible leakage.

(2) Sample must not be drawn through an iron pipe which is permitted to get hot for this will change the gases coming through it. A water-cooled iron pipe or a porcelain tube is preferable if the sample is taken from a hot portion of the furnace.

(3) The sample should be drawn from a portion of the furnace where the gases are passing at a considerable velocity and where there is the greatest possible agitation which will produce thorough mixing. A good point for this is in the down-take between the port and the top of the checkers.

(4) Samples should never be allowed to remain for any length of time in a container which contains water for this results in a surprising amount of CO_2 being absorbed by the water.

(5) In general, samples should be analyzed as soon as possible after taking and reagents used in the Orsat apparatus should be renewed frequently.

CORNING GLASS WORKS
CORNING, N. Y.

THE DETERMINATION OF POROSITY OF CHINA BY THE WATER SOAKING METHOD[1]

By Edward Schramm

ABSTRACT

Comparative tests show that prolonged soaking is more effective than boiling in attaining saturation of nearly vitrified ware, and a period of 4 days' immersion in cold water is recommended.

The subject of determining porosity has been exhaustively treated by Washburn and his co-workers,[2] who developed standard methods using liquids and gases as the pore-filling medium. Many of these methods require special apparatus and technique. Our problem was to make porosity determinations on vitrified china as a means of plant control and to make the method available to untrained men. For this purpose we carried out a brief study of the water soaking method on glazed and unglazed samples of vitrified and nearly vitrified ware. The samples were broken from plates having a thickness of approximately 0.2 inch. The ware used had a specific gravity of 2.36 to 2.40. The aim of the work was threefold: (1) To determine a suitable size of test-piece; (2) To compare the results by boiling and by cold soaking; (3) To ascertain whether the test could be applied to a glazed piece without grinding off the glaze.

For the purpose of the test we selected three pieces of properly fired ware, three of decidedly underfired, and three of very badly underfired. These are designated A, B, C, respectively. The biscuit plates were broken in two and half of each plate glazed and fired in the glost kiln, a procedure which, it was assumed, would not alter the porosity. Pieces were broken from the center of the plates in such manner that all of the edges were fractured. The results on different periods of exposure, etc., represent separate runs on identical test-pieces which were dried and reweighed between determinations. All weighings were made on a chemical balance; for the wet weighing the piece was quickly dried with a damp towel and introduced into a weighing bottle, thus avoiding loss during the weighing. The results are given in Tables I and II.

The general conclusions drawn from the above data are: (1) Prolonged soaking is essential and boiling does not hasten the penetration sufficiently to permit dispensing with the soaking period. This result is directly contrary to that reported by Foster[3] working on porous clay tile. The necessity for the soaking period is pointed out by Washburn and Footitt.[4] (2) No higher results are obtained by a combination of boiling and long

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Whitewares Division).

[2] *Jour. Amer. Ceram. Soc.*, **4** [11], 916; [12], 961; *Ibid.*, **5** [1], 48; [2], 112; [8], 527.

[3] *Ibid.*, **5** [11], 788.

[4] *Ibid.*, **4** [12], 979.

soaking than by soaking alone. The boiling may therefore be omitted, thus simplifying the test and avoiding the dangers of loss by solution and gain by rehydration as found by Washburn.[1] (3) While no attempt has

TABLE I

PER CENT ABSORPTION LARGER TEST-PIECES

No.	Weight of piece, grams	Biscuit: Boil 2 hrs. Cool quickly	Boil 4 hrs. Cool quickly	Boil 6 hrs. Soak 16 hrs.	Soak cold 96 hrs.
A-1	12.1100	0.05	0.05	0.10	0.07
A-2	23.4897	0.01	0.04	0.03	0.01
A-3	12.0270	0.07	0.11	0.15	0.00
B-1	18.1685	0.94	1.43	1.85	1.95
B-2	24.5646	0.84	1.01	1.71	1.91
B-3	16.8330	0.95	1.20	1.85	2.02
C-1	14.1830	2.03	2.34	2.43	2.64
C-2	16.2885	1.70	2.10	2.61	2.64
C-3	15.8239	1.91	1.94	2.28	2.51

No.	Grams	Glazed: Boil 2 hrs. Cool quickly	Boil 4 hrs. Cool quickly	Boil 6 hrs. Soak 16 hr.	Soak cold 96 hrs.
A-1	26.0286	0.005	0.006	0.008	0.011
A-2	19.0122	−0.011	−0.005	0.0	0.0
A-3	11.6485	0.0	0.0	0.0	0.0
B-1	17.5543	0.40	0.57	1.30	1.65
B-2	25.6868	0.67	0.59	1.42	1.67
B-3	20.0985	0.41	0.44	1.11	1.57
C-1	17.1429	1.03	1.00	1.92	2.13
C-2	11.1353	1.29	1.30	1.97	2.20
C-3	20.3000	0.88	0.95	1.80	2.00

TABLE II

PER CENT ABSORPTION SMALLER PIECES

No.	Weight of piece, grams	Biscuit: Boil 6 hrs. Cool quickly	Boil 6 hrs. Soak 70 hrs.	Soak cold 98 hrs.
A-1	8.8360	0.10	0.10	0.08
A-2	5.9220	....	0.08	....
A-3	6.6760	....	0.10	....
B-1	8.7100	1.49	2.16	2.04
B-2	8.2800	1.33	1.86	1.87
B-3	6.4750	1.47	1.90	1.92
C-1	6.4250	2.34	2.73	2.73
C-2	9.3940	2.14	2.57	2.55
C-3	7.5880	2.20	2.61	2.50

[1] *Jour. Amer. Ceram. Soc.*, **4** [12], 971.

TABLE II (*continued*)

PER CENT ABSORPTION SMALLER PIECES

No.	Weight of piece, grams	Glazed: Boil 6 hrs. Cool quickly	Boil 6 hrs. Soak 70 hrs.	Soak cold 98 hrs.
B-1	9.6330	0.70	1.61	1.58
B-2	8.6400	1.04	1.69	1.69
B-3	8.9870	0.65	1.54	1.56
C-1	10.4745	1.39	2.06	2.10
C-2	8.7090	1.63	2.31	2.15
C-3	8.8940	1.64	1.94	1.96

been made to determine true porosity by a standard method, the fact that similar values were obtained with test-pieces of different sizes indicates that saturation must have been practically complete. (4) The saturation of the glazed pieces was 80% that of the unglazed so that it is possible to estimate the porosity of a small glazed piece with fair accuracy provided fresh fractures are exposed on the edges.

The recommended procedure for determining porosity of china by water absorption is to break out a test piece of such shape that no part shall be distant more than $^3/_8$ inch from a fractured edge; weigh this piece accurately on a chemical balance, soak in cold water for four days, dry quickly with a damp towel and weigh in a stoppered weighing bottle. In this manner the simple water-soaking method may be made to give consistent results and we have been able with its aid to follow out vitrification range curves passing from underfire to overfire, the results checking the more accurate determination of bulk specific gravity.

ONONDAGA POTTERY CO.
SYRACUSE, N. Y.

COMPARATIVE TESTS OF POROSITY AND SPECIFIC GRAVITY ON DIFFERENT TYPES OF REFRACTORY BRICK[1]

By E. E. Pressler[2]

ABSTRACT

Comparative data of porosity and specific gravity on several types of refractory brick are presented. Apparent porosity is obtained directly by the water absorption and air expansion methods. Total porosity is calculated from the true specific gravity and apparent specific gravity is calculated from the observed porosity values.

The results indicate (1) a more accurate measurement of open pore space in bricks by means of the air expansion method than by water absorption, and (2) the absence of sealed pores in some types of refractory brick.

Purpose of the Investigation

In order to study the relative value of porosity and specific gravity data obtained by different means, comparative tests were made upon several types of refractory brick.

Procedure

Porosity was determined directly by the water absorption method and by means of an air expansion porosimeter.[3] True specific gravity was determined by the pycnometer method upon the ground brick material. Apparent specific gravity was calculated from the observed porosity values, and total porosity was calculated from the true specific gravity. All calculations were based on the same weight and volume data, and uniform methods of testing were followed throughout, in order to render the results comparable.

Method of Testing

Porosity by water absorption was determined by partially immersing the bricks in water and boiling for 1 hour, and then immersing completely and boiling for 5 hours. A soaking period of 24 hours was allowed.

Porosimeter tests were made upon the bricks dried at 110°C and cooled under a bell jar containing calcium chloride. The air in the auxiliary air container was artificially dried.

The true specific gravity determinations were made upon material passed through a 100-mesh sieve and dried at 110°C to constant weight. Tests were made upon samples of from 5 to 8 grams, and toluene was used as the reference liquid.[4] Weighings were made at constant temperature,

[1] Published by permission of the Director, U. S. Bureau of Mines.

[2] Ceramic Assistant, Ceramic Experiment Station, Bureau of Mines, Columbus, Ohio.

[3] The apparatus is described under the title "A Simple Brick Porosimeter," *Jour. Amer. Ceram. Soc.*, **7** [3], 154(1924).

[4] Toluene is preferred to water because it is relatively less active with the brick material. It has the disadvantages, however, of a higher vapor pressure and coefficient of expansion than water at room temperatures.

and the specific gravity of toluene was determined directly for the temperature of weighing. Entrapped air was removed by means of a vacuum pump.

Results

The results obtained for series of different types of bricks are given in the tables.

TABLE I

COMPARATIVE RESULTS OF POROSITY AND SPECIFIC GRAVITY

SERIES A—SILICA BRICK

Brick No.	Per cent absorption	Porosity		Per cent sealed pores	
		Porosimeter	Total calcd. from sp. gr.	Absorption	Porosimeter
1	27.12	28.31	28.34	1.22	0.03
2	27.60	27.98	28.04	0.44	0.06
3	27.55	28.22	28.07	0.52	−0.15
4	26.78	28.76	28.64	1.86	−0.12
5	27.06	27.61	27.79	0.73	0.18
6	26.79	27.19	27.10	0.31	−0.09

Brick No.	Specific gravity calcd. from porosity		
	Absorption	Porosimeter	True
1	2.293	2.332	2.333
2	2.309	2.321	2.323
3	2.312	2.334	2.329
4	2.300	2.327	2.322
5	2.306	2.324	2.330
6	2.306	2.310	2.307

TABLE II

COMPARATIVE RESULTS OF POROSITY AND SPECIFIC GRAVITY

SERIES B—MAGNESITE BRICK

Kiln level	Per cent absorption	Porosity	
		Porosimeter	Total calcd. from sp. gr.
Top	24.91	25.69	25.69
Top	29.35	30.56	30.56
Middle	26.81	27.71	27.85
Middle	24.65	25.43	25.61
Bottom	25.66	25.96	25.96
Bottom	28.43	29.53	29.53

Kiln level	Per cent sealed pores[1]	
	Absorption[2]	Porosimeter[3]
Top	0.78	0.00
Top	1.21	0.00
Middle	1.04	0.34
Middle	0.96	0.18
Bottom	0.30	0.00
Bottom	1.10	0.00

[1] Possibility of calculating the sealed pores from the true and apparent specific gravities was first developed by Ross C. Purdy, *Trans. Amer. Ceram. Soc.*, **10**, 367 (1908); *ibid.*, **11**, 69(1909).

[2] Calculated from data obtained in porosity by absorption method.

[3] Calculated from data obtained by porosimeter method.

Kiln level	Specific gravity calcd. from porosity: Absorption	Porosimeter	True
Top	3.497	3.552	3.552
Top	3.485	3.556	3.555
Middle	3.500	3.550	3.564
Middle	3.510	3.552	3.561
Bottom	3.529	3.558	3.556
Bottom	2.496	3.544	3.544

TABLE III

COMPARATIVE RESULTS OF POROSITY AND SPECIFIC GRAVITY
SERIES C—FLINT FIRECLAY BRICK

Cone of firing	Per cent absorption	Porosity: Porosimeter	Calcd. from true sp. gr.
4	23.98	26.28	27.74
5	23.54	26.58	29.41
6	23.74	26.65	29.44
9	23.16	25.94	29.68
11	22.65	25.40	31.48
12	22.34	25.63	32.57

Cone of firing	Per cent sealed pores: Absorption	Porosimeter
4	3.76	1.46
5	5.87	2.83
6	5.70	2.79
9	6.52	3.74
11	8.83	6.08
12	10.23	6.94

Cone of firing	Specific gravity calcd. from porosity: Absorption	Porosimeter	True
4	2.537	2.616	2.668
5	2.511	2.615	2.721
6	2.468	2.565	2.667
9	2.476	2.571	2.706
11	2.379	2.467	2.686
12	2.357	2.462	2.715

TABLE IV

COMPARATIVE RESULTS OF POROSITY AND SPECIFIC GRAVITY
SERIES D—PLASTIC FIRECLAY BRICK

Heat treatment	Absorption	Porosimeter	Calcd. from true sp. gr.
Soft Burned	21.91	22.84	22.84
Soft Burned	21.93	22.73	22.56
Medium Burned	20.50	21.19	21.44
Medium Burned	20.79	21.27	21.59
Hard Burned	12.61	15.68	16.00
Hard Burned	12.02	15.69	15.93

TABLE IV (*continued*)

COMPARATIVE RESULTS OF POROSITY AND SPECIFIC GRAVITY

SERIES D—PLASTIC FIRECLAY BRICK

Heat treatment	Per cent sealed pores		Specific gravity calcd. from porosity		
	Absorption	Porosimeter	Absorption	Porosimeter	True
Soft Burned	0.93	0.00	2.667	2.694	2.694
Soft Burned	0.63	−0.17	2.665	2.668	2.682
Medium Burned	0.94	0.25	2.635	2.653	2.661
Medium Burned	0.80	0.32	2.643	2.659	2.670
Hard Burned	3.39	0.32	2.564	2.651	2.661
Hard Burned	3.91	0.24	2.546	2.649	2.657

Discussion of Results

Series A. Silica Brick

This series consists of silica brick taken from different locations in a commercial kiln. The heat treatment ranged from cones 17 to 19.

Porosity by water absorption is seen to be lower than the corresponding porosimeter values. The porosimeter values compared with calculated total porosity, show the absence of sealed pores. These relations indicate that these bricks have no pores sealed to the air expansion effect, but that a certain percentage of pore volume remains "sealed" to water penetration effects.

Specific gravity values are more generally compared in silica brick than porosity values, since they indicate the effect of heat treatment more directly.[1] The apparent specific gravity, calculated from water absorption data, is found to be lower than the determined true specific gravity.[2]

Since the apparent specific gravity, calculated from porosimeter data of porosity, agrees within experimental limits with the determined true specific gravity, the porosimeter method may be used for obtaining approximately true values of specific gravity. This method has advantages over direct specific gravity determination, inasmuch as the testing procedure is more rapid and less exacting and requires no mutilation of the test specimen. It is particularly well adapted for use in kiln firing control.

Series B. Magnesite Brick

The magnesite brick were also taken from different locations in a commercial kiln. The heat treatment ranged from cones 16 to 18.

The magnesite brick show the same general behavior as the silica brick and the same observations apply. A correspondence between specific gravity and important physical properties of magnesite brick is pointed out by McDowell and Howe.[3]

[1] The porosity of dry pressed brick depends primarily upon the pressure applied in forming, while specific gravity depends only upon the density of the material.

[2] A similar discrepancy between apparent and true specific gravity of silica brick is found by Office, *Jour. Amer. Ceram. Soc.*, **2** [10], 832–35(1919); Harvey and McGee, *ibid.*, **5** [4], 219 (1922).

[3] *Ibid.*, **3** [3], 184(1920).

Series C. Flint Fire Clay Brick

This series of bricks was taken from different locations in a rectangular down-draft kiln showing an usually wide range of heat treatment. These bricks are flint fire clay grog bonded with plastic fire clay. They were machine molded from soft mud.

The observed porosity values show a greater disagreement than for silica or magnesite brick. Both the absorption and the porosimeter data, compared with calculated total porosity, indicate a certain percentage of sealed pores.

With progressive heat treatment, a decrease of open pore volume takes place concurrently with an increase of sealed pore volume. It is apparent, therefore, that neither open pore nor total porosity, considered alone, gives a positive indication of the state of the ware. Specific gravity values show no regular relation to degree of heat treatment. For these brick, it appears that exact indication of heat effect requires both porosity and specific gravity determinations, the latter values being used to calculate total porosity.

Series D. Plastic Fire Clay Brick

This series consists of bricks taken from regular stock and classified as soft, medium, and hard burned. The composition is straight plastic fire clay. They were made by the stiff mud repress process.

The observed porosity values show a greater disagreement in densely burned than in softer burned bricks. The porosimeter values, compared with calculated total porosity, indicate a very slight development of sealed pores.

Specific gravity values appear less indicative of heat treatment than porosity values. For these brick, porosimeter values of porosity may be considered as representing total porosity, without significant error.

Conclusions and Observations

The following points are brought out:

1. Porosity by water absorption is lower than true open pore values, particularly in the case of densely burned brick.
2. Porosity values of silica and magnesite brick are less indicative of heat treatment than are specific gravity values.
3. Different types of fire clay brick show a marked variation in the volume of sealed pore space developed.
4. Specific gravity values, as such, are not reliable indices of heat treatment of fire clay brick, but may be useful to calculate total porosity.
5. Porosimeter values of porosity approximate total porosity of fire clay brick in some cases, but not in others.
6. An important observation is that the silica and magnesite brick are found not to develop sealed pores in the process of firing.

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NOTES ON A COMPARATIVE TEST OF QUICKLIMES FOR SILICA BRICK MANUFACTURE[1]

By L. J. Trostel

ABSTRACT

In attempting to evaluate lime for control purposes in the manufacture of silica brick, it was found that the most consistent results are obtained by using a figure based on the *total* calcium oxide as compared with the A.S.T.M. *available* calcium oxide content. In addition, the particular test used serves as a practical basis for the comparison of the numerous quicklimes offered the silica brick manufacturer by lime dealers.

For some time it had been the practice in one of the plants manufacturing silica refractories of the writer's company to attempt to carefully check the quality of lime entering all green mud charges. For this purpose, each car load of quicklime upon arrival was analyzed for its available, or water soluble CaO and then from this the quantity was figured which would be necessary to add to the green mud charge to produce the percentage of CaO desired.

Owing to the great number of dealers offering supposedly high quality chemical quicklime and their contending claims it was felt that some practical plant test should be devised which would be applicable to all limes offered and serve as a basis of comparison.

Method of Use

In this plant, as in most plants manufacturing silica refractories, the lime before being added to the crushed ganister, is slaked in batches of from 27 to 32 pounds in sheet iron tubs with revolving paddle stirrers. After a 15 or 20 minute mixing period with hot water, the slaked "milk of lime" is run out of the tubs, through a screen with $^1/_4$-inch openings and then into the green mud charge in the wet pan.

The screen serves to catch the unburned and overburned pieces, clinkers and other foreign material which did not slake during the above period.

Lime for silica brick manufacture must be of as high CaO content as is possible and in addition slake rapidly enough that it will all be converted to "milk of lime" in the usual 15 to 20 minute period in the slaking tubs.

Test of the Lime

The test consists of obtaining the total weight of quicklime used during a day's run in the plant and analyzing a portion for the *total* CaO, as well as the *available* CaO, using A.S.T.M. methods throughout. Then all the residue from the above weight of lime, consisting of clinkers and overburned and underburned pieces which did not slake and were caught on the screens and remained in the bottom of the slaking tubs in the lime room, was saved, air-dried, weighed and analyzed for its total CaO content.

The data from these tests are shown in Table I.

[1] Recd. April 4, 1924.

TABLE I

TESTS ON QUALITY OF VARIOUS QUICKLIMES

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
Test No.	Lime used	Total calcium oxide	Available calcium oxide	Actual calcium oxide used = $b \times c$	Residue recovered	Total calcium oxide in residue	Actual calcium oxide in residue = $f \times g$	Loss lime expected = $c - d$	Loss lime actual = $\frac{h}{e} \times 100$
	Lbs.	%	%	Lbs.	Lbs.	%	Lbs.	%	%
1	4550	94.4	89.6	4295	62.5	54.7	34.2	4.8	0.8
2	5398	94.8	80.7	5117	31.0	57.6	17.9	13.3	0.4
3	5032	92.3	84.6	4643	27.0	48.3	13.0	7.8	0.3
4	4168	92.3	86.8	3847	35.0	56.2	19.7	5.5	0.5
5	5265	91.0	84.9	4791	31.0	43.7	13.5	6.1	0.3
6	3996	93.3	80.2	3728	20.25	55.1	11.2	13.1	0.3
Av.	4735	93.0	84.5	4404	34.5	52.6	18.3	8.4	0.4

The most striking thing shown by these data is first, the rather large differences in column "*i*" and "*j*" and second, the regularity of column "*j*" as compared with "*i*." This means that the A.S.T.M. method for determining available lime is not suitable as a basis for comparison of limes for this process and that the total lime is much better. This led to basing the weight of lime added to a charge of green mud on the *total* CaO content of the quicklime, instead of the A.S.T.M. *available* content which had heretofore been the practice. The results justified this change in practice.

Previously, muds would often analyze as much as 3% lime, compared with the 2.25% calculated. Now a variation of 0.2% either way from the 2.25 calculated is the maximum found when close attention is paid to the process. Anyone acquainted with the manufacture or use of silica brick will readily appreciate the value of being able to control the percentage of lime in the brick so that neither low lime with resulting poor bond and insufficient quartz inversion and expansion result, nor high lime with lowered fusion point and the long train of ills that accompany this condition.

The practice of calculating lime on the available basis probably had its origin in the apparent similarity of the A.S.T.M. test to the slaking operation in the plant, both water treatments, and therefore the assumption that only the available CaO was slaking up in the mixing tubs and got into the brick. The difference, of course, lies in the theoretical conception of the available lime as compared with what constitutes the available lime as found by experience in this particular process.

According to the National Lime Association, by the available lime is meant that portion of the total oxide content of the lime, either quicklime,

or hydrated lime, calculated as CaO, which is easily soluble in water and is thus available as a source of hydroxyl ions. It is true that the oxide content of the lime may be more available for one process than for another, the difference depending on the conditions for the reacting mixtures, etc. To illustrate, it is possible that a greater or less percentage of the oxide of the lime might be available in a causticizing reaction than would be available, for example, in a water treatment. If this is true a different method for determining the so-called available lime would be necessary for each process.

Actually, the real available lime in quicklime in the manufacture of silica refractories in this plant is not exactly that defined by the National Lime Association and detected by the A.S.T.M. method but includes some of the materials which are considered unavailable lime. This is due to the fact that the screens under the slaking tubs are large enough to allow fair-sized particles of some overburned lime (calcium silicate) and underburned lime (calcium carbonate) to pass through, and in such a test as the one described, these materials would get into the green mud and for all practical purposes become available lime.

The test just described has proved valuable in detecting whether, or not, the percentage of underburned and overburned stone, or clinkers is high, for these would be noticeable in the residue on the screens and the bottom of the slaking tubs and make the "lime efficiency" low. The test thus serves as a valuable comparative test in choosing a dependable, high quality quicklime from the numerous products offered the manufacturers of refractories by lime dealers.

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Joliet, Illinois

NOTE ON SECONDARY EXPANSION OF FLINT CLAY

By Fred A. Harvey

ABSTRACT

Certain flint fire clays show a secondary expansion, which may amount to several per cent, at a temperature much below that at which dangerous expansion begins. Some specifications discriminate unjustly against brick containing fire clays of this type.

The purpose of this brief note is to establish the fact that certain fire clays show an expansion at a temperature considerably below that at which they begin to "overfire."

There are a number of specifications for first quality fire-clay brick which recognize the fact that a clay brick which begins to overfire at a temperature of 1400°C is not suitable for use at high temperature. This fact is granted without argument. The specifications, however, do not admit that there may be expansion from any cause except overfiring. For example, the A.S.T.M. "Definition" for High Heat Duty Fire-Clay Brick No. C27-20, states that when the brick are heated for five hours at a temperature of 1400°C they shall not show a permanent expansion on cooling of more than 1%.

When the United States Refractories Corporation first undertook to make a brick to meet this specification it was found that most of the test brick expanded considerably more than 1%. All the clays used had a softening point of cone 32 to 34, including the bond clay. A chance remark by Mr. Young, Superintendent of the Barrett plant, formerly in charge of the Woodland plant, put us on the right track in our study of this failure to meet the A.S.T.M. definition.

Some 9-inch brick had come from the kiln which measured only $8^{7}/_{8}$ inches long. Mr. Young explained this by saying that the brick were too light-burned to be full length. It was his experience that it takes heavy firing to bring the brick up to full dimensions. This observation was speedily established as a fact.

We can say definitely that a light-burned brick which contains any considerable percentage of Morgan Run Hard Clay will be from $^{1}/_{16}$ inch to $^{3}/_{32}$ inch shorter than the same brick when hard burned.

Some brick made to accentuate this property, measured $13^{1}/_{2}$ inches after being burned to approximately 2200°F (1204°C), and full 14 inches after being burned in our silica kilns to a temperature of 2650°F (1454°C). Yet there is not the slightest evidence of overburning. There are no spots showing distortion, there is practically no trace of vitrification having started, as would be the case with overburning.

J. Spotts McDowell also has observed this expansion of clay brick between what is called a light burn and a hard burn.

After we had the facts before us it was not difficult to make a brick which would consistently pass a specification even more rigid than the A.S.T.M.

definition. Yet the fact remains that a high heat duty brick made to pass this specification would be entirely unsuitable for many uses.

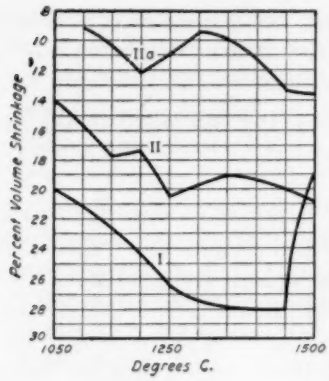

FIG. 1.

Is it reasonable to say that a brick burned to 2200°F is not a high heat duty brick while the same brick burned to 2400°F becomes a high heat duty brick?

The practical experience cited above is nicely corroborated by some laboratory tests made for us at Mellon Institute. Figure 1, Curve I, shows a typical volume-temperature curve for fire clay, Curves II and IIa show heat volume curves for Morgan Run hard clays. It will be noted that there is a contraction up to a temperature of about 1200°C then an expansion up to 1350°C then contraction to the highest temperature which could be reached. It is evident that even at 1500°C the temperature of overfiring has not nearly been reached. The clays have a softening point of about cone 33–34 and approximately the following chemical analysis. (Burned clay.)

SiO_2, 49.5; Al_2O_3, 44.4; Fe_2O_3, 2.5; TiO_2, 2.1; CaO, 0.2; MgO, 0.1; Alkalies 1.2.

Figure 2, Curve I, made at a different testing laboratory exhibits the same characteristic. This chart was kindly loaned for the purpose of this note. It represents linear change during a load test. It will be noted that starting at 1250°F (677°C) even under a load of 25 lbs. per sq. in., the brick expands 1.2% until a temperature of 2236°F (1224°C) is reached when contraction again starts. There is then a period of constant length and final collapse at 2755°F (1513°C). It will be noted that the temperatures given are somewhat lower than those recorded at Mellon Institute.

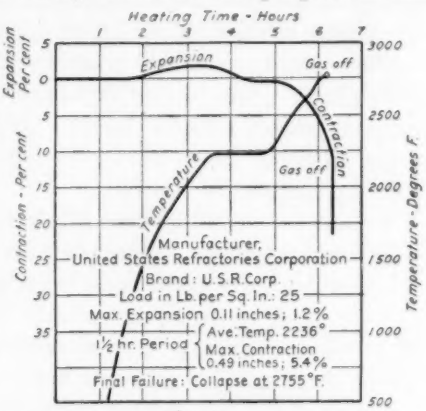

FIG. 2.

In some clays there is a secondary expansion, followed by contraction during heating, either in kilns or testing furnaces, which is entirely distinct from the expansion due to overburning. The expansion due to overburning indicates an inferior clay. This secondary expansion is an asset to the consumer in keeping walls and arches tight.

UNITED STATES REFRACTORIES CORPORATION
MOUNT UNION, PA.

INSULATION OF GLASS TANKS[1]

By W. K. Brownlee

The walls and bottom of a glass melting tank are insulated to give a longer life. The cause of rapid erosion must be determined before the remedy can be devised.

The tank blocks are more or less porous which gives opportunity for fluxing of the glass constituents with the clay of the tank blocks. The clay base undergoes alteration and is flushed away into solution exposing fresh surfaces to further reaction.

An outstanding feature of the effects of erosion, is the uneven vertical corrugations down the walls of the furnace and it was this that raised the question of insulation as a means of preventing or reducing to some extent the convection currents that are moving downward over the inner surface of the clay walls drawing down with them the most active fluxes from the hot surface. The walls of a pot suffer less from erosion than the walls of a tank, and it is possible that because the direction of the currents in a pot is directly opposite to what it is in a tank, that pot walls are not subjected to the hottest action of the fluxes. In the pot the convection currents are going up the walls from a cooler temperature zone and in the tank they are going down the walls from the highest temperature zone.

It is true that the colder the walls of a tank, the more the convection currents are accelerated. It is also probable that a wall of even thickness (no matter how thick) would not stop convection currents. So in the construction of this experimental tank we exposed six inches of the top row of the blocks to the atmosphere, and increased the thickness of a wall toward the bottom to compensate for downward heat losses.

The flux block lining of the tank was 8 inches thick in the wall, and the size of the tank was 4 feet wide, 6 feet long and 2 feet deep. The bottom was of 12-inch flux blocks, 12 x 18 x 24 inches. These were placed on solid masonry (fire brick), 24 inches thick under which was a course of Sil-O-Cel, $2^1/_2$ inches thick. The base was 13 inches larger than the space covered by the tank blocks. We then placed a 9-inch wall of good high grade fire brick laid tight and neat against the outside of the lining, 4 courses high. Then the thickness of this lining was reduced to 6 inches for two courses of brick in height, the finish was a row of brick $2^1/_2$ inches thick. Outside of all this was a facing of Sil-O-Cel ($2^1/_2$ inches thick) and steel bracing was outside of all masonry.

The tank was operated for 30 days at 2500° to 2600°F, melting from 1500 to 1600 pounds of raw batch without cullet, each 24 hours.

Fixed amounts of batch were introduced at regular intervals, in one end of the furnace, and the melted glass was ladled or gathered from the other

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Glass Division).

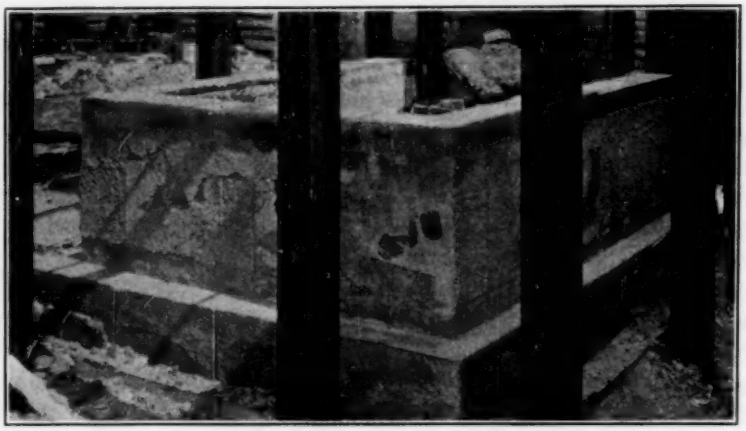

FIG. 1.

This photograph shows a glass melting tank four feet wide, six feet long and two feet deep.

The walls and bottom were insulated with fire brick next to the tank blocks and Sil-O-Cel outside of the fire-brick wall. The furnace operated at melting temperature for thirty days melting 1650 lbs. of bottle batch (no cullet used) each day. The new batch was filled on top at end which is removed, and ladled out of cylinder which was, when in position, near the end wall opposite from the wall removed. The wall linings were culled blocks and not specially burned, rather underburned, which was the main reason for calling them culls.

The purpose of the experiment was to determine if by insulation, increasing in thickness near the bottom, convection currents that evidently are responsible for vertical corrugated lines of corrosion could be retarded or eliminated. The appearance of the blocks clearly indicate that either convection or surface tension or both was eliminated greatly. The cracks in the end wall are probably due to shrinkage of the underburned clay. Glass at some joints did show through but progress was effectively interrupted by the fire-brick wall, as there was only a trace of metal outside of flux blocks.

FIG. 2.

end from a cylindrical ring with holes in the bottom for passage of the glass to the ring. In other words the tank was operated as a continuous melting furnace for 30 days.

At the end of this period the fire was let out for observation of the action of the operation on the tank walls.

There was no evidence of vertical lines of erosion, or any loss of metal through joints or masonry.

In discussing this question with glass manufacturers, we find a number that see much merit in the idea. Some raise the question of leaks through the wall and the answer to this is, a high grade fire-brick wall of the right quality of clay will not wear out or leak glass through it, until it becomes exposed to the action of fluxes, and this will not occur until the furnace lining has been removed by erosion, and loss through erosion on the lining will be reduced correspondingly to the retarding of convection currents.

BUCKEYE CLAY POT CO.
TOLEDO, OHIO

Discussion

MR. CRAWFORD: How much corrosion was there in the block in that period?

MR. BROWNLEE: In the 30 days there was no noticeable corrosion at all.

MR. CASSELMAN: I do not comprehend your explanation for the absence of the channels in the block.

MR. PAYNE (Chairman): As I understand it, as the glass came in contact with the wall of the tank it was cooled. Thus the glass was more dense after it was cooled than the glass near the center of the tank or underneath it, hence it would sink. When the outside wall of the tank was insulated the edges were not cool and, therefore, there was none of this downward movement at the sides and upward in the center and across the top.

MR. REED: Where could information be obtained as to specific gravity of glass at various temperatures from 200° up?

DR. INSLEY: I believe the Geophysical Laboratory has done some work on the specific gravity of other materials at high temperatures and perhaps on some silicate glasses, but not commercial glasses.

MR. REED: Inasmuch as this entire discussion hinges on the vertical flow of glass, and on the specific gravity, some very definite information should be used to back up the theory and results claimed. There is absolutely no information which has come to light which gives the specific gravity of glass at anywhere near 2000°F.

The possibility of the results that have been pointed out by this experiment are large enough to warrant test work to be carried on to obtain the specific gravity of glass at this temperature. It would at least more definitely vindicate those who favor glass-tank installation.

MR. YUNG: I wonder if it is a question of specific gravity or whether it is a matter of viscosity. It always seemed so to me, but I have never had an opportunity of trying it out. A number of people have taken the measurements of the glass temperature on the surface of the tank and at the bottom and on 42″ depths it was found to differ by as much as 400°C. The most noticeable place of corrosion, according to my observation, is over the throat of the tank, the throat block of course getting the greatest amount of corrosion, but also the block immediately over that throat block corroded away before the side blocks of the tank, and I have often wondered if perhaps that did not mean that we were drawing a larger tonnage over that surface than we did over the lower parts of the tank. There is always the thought, of course, that the temperature increases corrosion, but I think there are other factors which should be considered. The lower part of the tank may be so cold that perhaps there is very little motion of the glass there, consequently very little corrosion, not much pulling away of small particles of clay block from the surface and exposing new surfaces, whereas on the surface of the glass you have less viscosity and consequently a greater flow exposing a new surface continually which might perhaps explain the greater amount of corrosion at the metal line. The matter of insulation might help overcome this feature by increasing the amount of insulation in proportion to the drop in temperature of the glass from the surface to the bottom giving a more uniform temperature condition throughout the depth of the glass which would tend to move a greater mass of glass in the tank than just the surface.

MR. DIXON: In every instance known where insulation has been used on the tanks, we found that it decreased the life of the tank very materially, that the blocks disintegrated very much more rapidly, and experience in this always brings up many things that are really mysterious to those engaged in the business.

Mr. Yung's suggestion about the corrosion around the throat is one peculiar result that is known to everybody employing tanks of this kind, that is, the double compartment tank. One tank may have a production of 50 or 60 tons a day going through the throat. Another may have 15 or 20 tons production a day going through a throat the same size and the 60-ton tank will last just as long as the 15-ton tank. That seems to absolutely contradict the natural result that might be looked for, and yet, it happens.

To prolong the life of the tanks, everybody has tried just the opposite of insulation. They have air blown on the outside of the blocks to cool them or use water jackets in order to prolong their life. There is an experience I had some years ago. An accident happened to the furnace and it had to be put out about five weeks after it was started. It was a breaking bridge wall, and all of the glass ran into the basement. When the

furnace was cooled we found the walls were so badly eaten away in that five weeks that it was most astounding. It was the first time I had ever seen a furnace let out in such a short time, and I could not advise the owners of the tank whether to leave the blocks in or to replace them. They replaced them. I have had that experience several times since and I have come to the conclusion that the inside portion of the block is eaten away in a very few weeks. The outside 4 or 5 inches will last indefinitely if kept cool, so that it is proven that the thicker the walls the more rapidly they disintegrate.

One of the first tank undertakings in this country was a most ridiculous proposition. The window glass tanks that were built at Jeanette in 1887-88 were built by people who had no engineering capacity or knowledge of the subject whatever, and I was one of them. They made the walls of those tanks 39 inches thick, and in a few weeks all the blocks had sloughed off and all that clay material had gone into the glass until the tank walls were about 10 or 12 inches in thickness, and then it remained for an indefinite time.

What was the use of 39 inches of wall in a furnace of that kind?

These things all tend to convince me that insulation of the tank block walls is working in the wrong direction. If the walls of much thinner blocks are kept cool, it has been frequently demonstrated they will at least last longer in the outside portion. I have never seen a tank that was insulated that has run any length of time.

A six weeks' or four or five weeks' test, such as has been described here is not a test of sufficient length of time to prove anything. It should be a test of a year to give data for any positive conclusions.

MR. AURIEN: From my experience I would concur with Mr. Dixon. I feel that the inside of the blocks could be expected to have some protection by your glass devitrifying, or in a sense, a dormant glazing. Now if you heat the outside of the blocks the tendency is to keep that much hotter and bring fresh metal in contact with the newer clay at the surfaces. I think what we want is cooling instead of heating up to prolong the life of the furnace.

MR. YUNG: Mr. Brownlee happened to have talked with me on this matter some time ago, so that I am familiar with his idea and theory and to open the discussion I was simply presenting his idea to straighten out the thought and start the discussion. It seems to me that there is so much that is unknown about the life of a tank, the causes for failures in the tank, that I think it well to study the subject from the various angles. For example, the matter of the short life of a 39-inch block in a tank, which Mr. Dixon speaks of, might not have been due to the increased amount of heat on the inside surface as much as it was to poor construction of the block. As any of the clay men here will probably

admit, it is also a rather difficult proposition to properly burn a 39-inch block and get a homogeneous burning throughout, and if it is not burnt properly the interior of the block will be soft and is not going to last very long. I only mention this as a factor to introduce some discussion which may come up later from the causes for failures of tanks, which I think is well worth discussing.

MR. DIXON: The insulation of the refining compartment is old. We have been doing it for years, ever since we started to build these two-compartment tanks. The insulation consisted of a brick wall outside of the tank block wall on the refining compartment. That has become very dangerous now because the man who runs the furnace has to run the glass hotter. The machine production requires hotter glass, and we have had to take the insulation off of the working compartment.

MR. FLINT: I just tried to jot down a few things from memory that we took from some tanks; some of them are the averages of a few hundred. Approximately 5% or 6% of the heat, as I recall it as the average, is used up in melting and bringing the glass up to proper temperature, and about 5 or 6% is taken out by the hot glass as it leaves the tank, which is necessary because it has to be used hot on the machines. The stack carries a little under 20% of the heat. In other words, putting it in dollars for every dollar's worth of heat you are expending about 19 or 20 cents on the stack. That is not all loss, because $^3/_4$ or more of this is used in mechanically lifting the products of combustion out of the down-going checker chamber. The rest of it is due to radiation.

In our practice approximately $^1/_2$% to $3^1/_2$% of the heat value of the gas is lost in excess air. That gives approximately 28% to 30% of the heat that is put into the tank. The rest of it is lost by radiation. This heat was distributed about as follows: Regenerators and the flues took about 6%; the regenerators themselves probably lost about 3%. In other words, 97% of what went in went back into the tank. Some of that we could have corrected by insulation. The flues took out some; the crown, as we calculated it, took around 20% or a little under, the front half probably takes 8% or 9% and the back half 9% or 10%, because it gets more of the direct flame, and the off-takes took more—nearly 15%.

You cannot say, however, that that is true of all off-takes; ours might be a little more chopped up than the rest, although I do not believe so. The off-takes represent as much surface to the air as the crown will and in such a way, like a radiator, that they give off the heat. The side and the bridge together take about 20% or a little under, according to the glass, the heat, etc., and the bridge takes about 10%.

If you are going to economize on fuel you will find it is a big loss.

We figure that there are only two ways to correct this: Increase the amount of glass that goes through the tank so that that which is exposed

to the heat can take it up and pass it on to the used article. If you raise the amount of heat that the glass gets and increase it 10% to 20%, you are getting it directly back in your own pocket, but you cannot do that generally.

The stack can be improved a great deal. Some stacks have rather thin walls, some of the steel stacks may have a small layer of brick, and they could be protected some. That only represents 5%. Most of that is necessary to the crown, etc., it is possible and it has been done. To insulate, we shall take the worst one, the off-takes—the fire is going right into the off-takes from the tank and has practically got the temperature of the flame. It is a high potential for heat loss and there is plenty of surface for radiation. Those have been insulated—they are beginning to do it with steel plants and are successfuly doing it. I believe with Mr. Dixon that it is perfectly all right to insulate the front end of the crown, and I even feel that we can do it now with our high temperature. When it comes to the side wall and the bridge, we are buying bigger blowers and putting more of them on there, because the tank boxes that used to last are not lasting now and we are trying to do our best to hold them. The measurements we have taken of the amount of wind delivered to tanks for side wall and bridge wall cooling have indicated somewhat in a rough manner, although it is hard to check, that the tanks with the least amount of wind are not doing quite so well. When we give them more wind we feel that we are getting better results out of them. If the flues, which are sometimes in damp ground, which is one of the nicest conductors of heat there is, could be insulated and water-proofed, it would help out. I find that the Illinois Pacific Glass Company, who are burning oil, have insulated a 12-inch crown with two layers of silica on top and insulated their off-take and they have done that for two fires at least. Well, if that's the case I do not see why—they insulated, by the way, the back end as well as the front end of the crown—I do not see why we could not go part way on that. I do not know that I would insulate the back end as it is such a proposition but I am just citing it as a fact. It has been done and has worked but I do not know anybody who has successfully insulated a flux block and kept the block there.

MR. BROWNLEE: The discussion is mostly unfavorable to the idea proposed. I observe that the prevailing thought is that the insulation is sure to create a higher temperature in the blocks which will cause the clay to be more easily attacked as evidenced by the more rapid corrosion when excessive temperatures are used. As a matter of fact just the reverse of this is true.

Due to cold bottoms and side walls of glass tanks a rapid movement of the metal is set up over an area that represents about one-third of the total melting area. This of course reduces the time factor for melting,

to one-third of what it would be, if the body of glass was all equal in temperature and viscosity, so under a slower and more uniform movement of the entire body of glass a *lower temperature* would, with the *increased time* allowed for the melting, be used.

This slower and more uniform movement of the entire body of glass cannot be obtained by cooling the walls and bottom. The cooling of the side walls does produce convection currents or rapid precipitation down the walls, also a surface tension of glass on clay, which probably removes the clay very rapidly while the wall is of full thickness. It may be that at this time, surface tension is all on clay and it may be that when the wall has worn to a thinness through which sufficient cooling can be transmitted, the surface tension is removed from the clay wall and the tension is then on the glass which is held congealed on the wall. If clay walls should not be kept at a high temperature, how was glass ever made in pots profitably? Pots do not suffer from corrosion as do tank walls, and yet all the temperature must be conducted through the walls, and if it were not for the shrinkage cracks that come on the inner face of pot walls, due to sudden cooling when batch is introduced, the pot walls would last as long or longer than tank walls.

This is due to proper heat conditioning of clay which is a natural sequence with pots and clay to withstand the action of glass should be burned to a temperature in excess of the temperatures to be used in melting glass. This will insure against physical change through shrinkage, and greatly decrease absorption of alkalies.

If we were to attempt to burn tank blocks to the degree of temperature required to condition them the best, we would first have to consider the practical dimensions of blocks that could successfully be burned to the right degree without excessive losses, and the difficulty of reheating when placed in the tank walls.

I am of the opinion that this can be done with blocks that do not weigh over 125 lbs., and suggest these blocks be not over 8 inches thick, 12 inches wide, and 18 inches long, or even less than this, say 8 x 8 x 12 inches. The number of joints is not as important as to get the general condition correct to make insulation do in the glass business, all that is possible for it to do in any other line. Insulation does not create temperatures that are disastrous to clay blocks. The temperature that does is created from another source which is desirable to reduce to the advantage of the clay blocks and conservation of fuel.

PREPARING AND SPRAYING A GLAZE SLIP WITH ESPECIAL REFERENCE TO THE CONTROL OF THE VARIOUS OPERATIONS[1]

By Robert Twells, Jr.

ABSTRACT

The article describes methods at the Champion Porcelain Company in glazing porcelain cores for spark plugs. One-day requirement of glaze slip is intimately mixed and ground in a pebble mill to pass 325 mesh, then stored separately and gently agitated for several days while firing, specific gravity and viscosity tests are being made. Careful records are kept regarding each batch. Some of the problems met in the preparing and spraying of the glaze slip are described.

Introduction

The application of a coating of slip to the surface of the ware is an important step in the manufacture of many ceramic products. At the Champion Porcelain Company considerable attention has been given to one phase of this subject: namely, the spraying of a thick coating of glaze slip on to a dry, unfired porcelain body. The ware in this case consists of spark-plug cores which present an unusually difficult spraying problem. The requirements are: (1) That the core be sprayed completely with the exception of the shoulder, the neck, the cap, and the bore (Fig. 1). The shoulder and cap must be kept free from glaze to prevent the cores from sticking to one another and to the sagger in firing; and, more important, the shoulder, cap, and neck must conform to standard dimensions within a limit of tolerance of 0.008 of an inch. Obviously such close limits could hardly be maintained with glazed surfaces especially if the spraying were uneven. (2) Between the glazed and unglazed surfaces the dividing lines must be straight, distinct and at the same place on every core; and (3) a spark-plug porcelain requires an abnormally heavy coating of glaze slip owing to the nature of the body and its high maturing temperature. The glaze itself melts about cone 11 down; the body does not vitrify until about cone 17. Between these temperatures the body readily absorbs a considerable

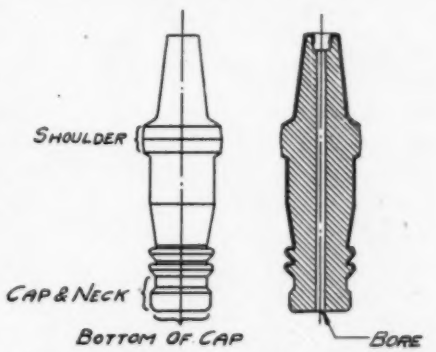

Fig. 1.—Sketch showing the parts of the spark-plug, porcelain core which are required to be glazed. This is indicated by the double outline of the cross-section.

[1] A contribution from the Research Division of the Champion Porcelain Company and the Jeffery-Dewitt Insulator Company. Presented at the Atlantic City Meeting, Feb., 1924 (Whitewares Division).

portion of glaze, and would suck bare any spots too thinly sprayed. On the other hand the slip cannot be applied too heavily or the glaze would flow in firing and collect on the lower portions of the core.

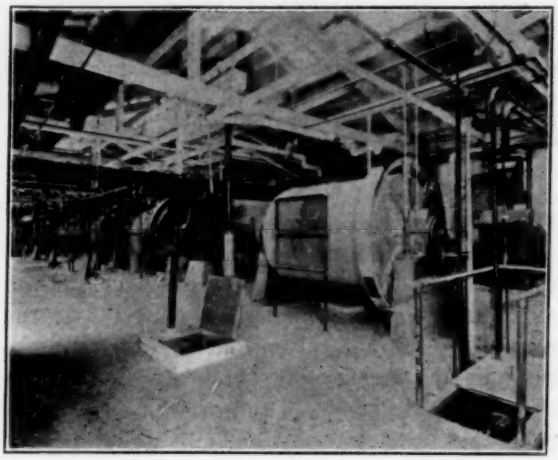

FIG. 2.—View of one section of the mill room.

Glaze Slip Preparation

Intimate mixing and thorough grinding are accomplished in a pebble mill 6 x 8 feet revolving at 15 r.p.m. (Fig. 2). The mill is lined with sillimanite porcelain bricks and carries five tons of balls made of the same body. The balls are kept within certain size limits and the same amount of materials and of water used. This gives a finished slip of a definite specific gravity and ground to pass through a 325-mesh lawn.

The mill is discharged into a blunger 9 x 9 feet situated in the floor below the mill. The mill is thoroughly washed with a measured quantity of water and the washings added to the slip in the blunger.

Glaze Slip Storage Room and Circulation System

From the blunger the slip is passed through a hexagonal revolving lawn for removal of foreign particles coarser than 120-mesh and then into one of four storage tanks (Figs. 3 and 4). These are wooden tanks each 6 feet 4 inches by 5 feet holding one mill charge. Four semicircular blades rotating at 30 r.p.m. near the bottom of the tanks cause a current in the slip to rise at the tank's

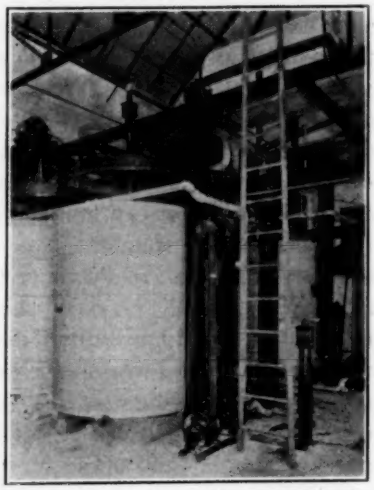

FIG. 3.—View of a section of the glaze slip storage room, showing the overhead location of the lawn, the storage tanks, the method of agitation of the slip, and the two centrifugal pumps for forcing the slip through the supply line.

outer edge and fall at the center. The slip is thus allowed to age until required for use and meanwhile corrected for specific gravity and viscosity.

The slip is withdrawn by means of a centrifugal pump from the bottom of a tank, forced through a two-inch supply pipe extending over each spraying machine and returned to the same storage tank through a pipe extending down to within eighteen inches of the tank bottom. The slip thus circulates over the hopper of each spraying machine, and can be drawn into the hopper as required for use.

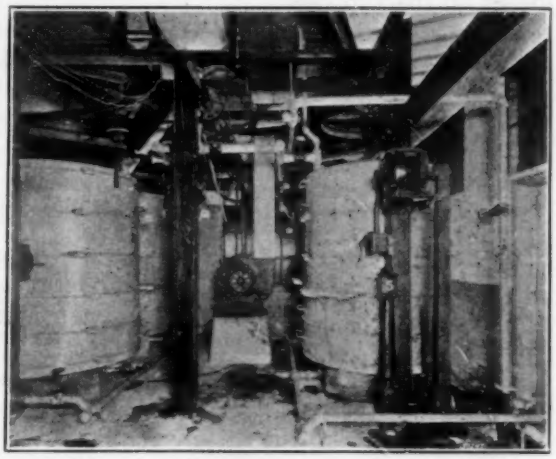

FIG. 4.—Another view of the glaze slip storage tanks. Note especially the pipes through which the slip is circulated to the spraying machines.

Spraying Equipment (Figure 5)

There are 10 spraying machines each with 20 spindles set vertically on a $11\,^5/_8$-inch circular revolving table. Inside of the glaze hopper is a smaller revolving hopper which serves the double purpose of lawning and agitating the slip. Each of the vertical spindles rotates on its axis as the table revolves, thus exposing the complete circumference of the core as it passes the spraying nozzles. There are two nozzles to a machine, one set to spray the upper and one the lower parts of the core. The slip is atomized by compressed air at a definite uniform pressure. Galvanized iron guards hinged at one end for easy adjustment protect the portions of the core which are to be left unglazed. The cores are packed directly from the spindles into carborundum saggers (Fig. 6), the bottoms of which have been

FIG. 5.—One of the spraying machines.

freshly painted on with an organic paste. This paste dries and holds the cores firmly upright while the sagger is being trucked about and being loaded on the kiln cars.

Figure 7 shows the method employed for glazing the cores before the present spraying system was installed. The core was held, while being dipped, by means of air pressure applied against the inside of the bore.

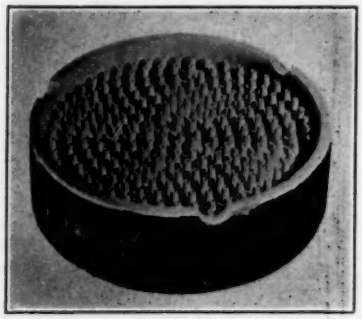

FIG. 6.—A sagger filled with sprayed cores ready for the kiln.

Methods of Control

(1) The first control test consists of careful chemical and physical tests of all glaze materials before being released for use.

(2) The next step is determination of the water content of each material allowance made for moisture.

(3) For each mill of glaze slip, a card is filled out giving the glaze number, the amount of each ingredient, the bin from which each is to be taken, the length of time of grind, and the amount of water to be added in grinding and washing. This card is given to the foreman in charge who checks each item as it is weighed. He fills in the mill number, the date, and the time of starting and stopping the grind. The card is then returned, checked, and filed.

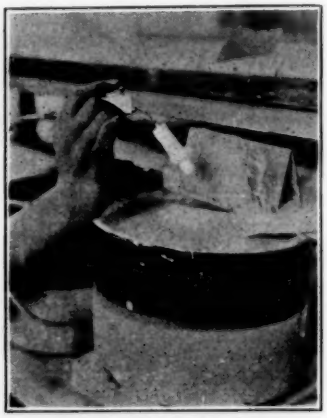

FIG. 7.—Applying the glaze slip to a core by dipping. This method was in use before the adoption of the present method of spraying.

(4) At the finish of the grind, a sample of the slip is sent to the Process Laboratory for a fineness test through a 325-mesh lawn; the amount failing to pass is noted.[1]

(5) Another sample is taken after the slip is in the storage tank. This is divided into two parts.

(*a*) One part is sent to the Process Laboratory where 25 regular cores are dipped in it. These are hurried into a kiln and are out, ready for examination, before the glaze mix itself is needed for production. These fired-porcelain cores are tested for impact strength and for resistance to heat changes. Both of these properties might be adversely affected by

[1] This residue should be practically nil.

even a slight mistake in the proportions of the glaze ingredients.[1] If the tests prove normal the glaze slip in the storage tank is released for production.

(*b*) The second portion of the sample is tested for specific gravity and viscosity (Fig. 8). The former is determined by weighing 100 cubic centimeters of the slip, and the latter by the time taken for 210 cubic centimeters to flow through the orifice of a Bureau of Standards Viscosimeter.[2]

These two tests show whether or not a correction is needed. The specific gravity at this stage is usually between 1.460 and 1.465. With the specific gravity within these limits the viscosity of the regular slip should usually be 50 to 55 seconds.[3] If the viscosity is too low, an acid salt is used to increase it; if the viscosity is too high, additional water and, in extreme cases, a basic salt is added to lower it.

FIG. 8.—Laboratory of the production division where routine control tests of the glaze slip are made. The view shows the manner of taking the viscosity test. The balance at the right indicates the method of determining the specific gravity.

(6) As the glaze slip ages, the viscosity drops. The day before it is to be used another specific gravity and viscosity determination is taken to insure that the slip is normal. Additional correction can still be made at this stage. The next day the glaze slip is pumped through the circulation line to the spraying machines. While the slip is being sprayed, specific gravity and viscosity tests are taken several times during the day by the Production Division on samples drawn from the tank (Fig. 8).

During the spraying the specific gravity of the slip usually lies within the limits 1.445 to 1.460. These correspond, respectively, to water contents of 50.4% to 49.3% in the slip. At the same time the viscosity usually is held between 42 and 50 seconds. These would seem rather wide limits for viscosity. Actually, however, other factors affecting the slip, such as the length of aging, the amount and kind of electrolytes, and the temperature, greatly narrow these limits for any given set of conditions.

(7) All of the data regarding a tank of glaze slip, date of milling, nature of the materials, results of the tests, amount of corrections, and comment as

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[1] F. H. Riddle and J. S. Laird, "The Control of Glaze Fit by Means of Tensile Test Specimens," *Jour. Amer. Ceram. Soc.*, **5** [8], 500(1922).

[2] A. V. Bleininger, "Use of Sodium Salts in the Purification of Clays and in the Casting Process," Bur. Stand., *Tech. Paper* **51.**

[3] Water has a viscosity of 25 seconds with this particular apparatus.

to its spraying qualities are all recorded for future reference. Accompanying each platform load of filled saggers is a ticket showing the number of the spraying machine and the date of spraying. If the ware should come from the kiln improperly glazed, it is a relatively easy matter to trace back and study the conditions surrounding each operation of preparation and spraying.

Notes on Preparation and Spraying of the Glaze Slip

This paper would hardly be complete without reference to some problems met in dealing with the glaze slip in production.

(1) Making the Glaze Slip

The glaze formulae used in this plant require a high raw clay content.[1]

Considerable difficulty has been caused by changes in the viscosity of the slip from mill to mill due to variations in the clays used. This is illustrated by examples shown in Table I. These three mills of slip received practically identical treatment. The differences in initial viscosity were due to variations in one of the clays used when taken from three separate shipments.

TABLE I

Tests taken		Specific gravity	Viscosity	Remarks
Time	Date	Glaze 745	Milled 7–4–1923	
3:00 P.M.	7–5	1.459	Would not flow through viscosimeter	
7:30 A.M.	7–9	1.458	70 1/5 seconds	
Percentage of water in slip increased 0.14% by weight				
4:10 P.M.	7–10	1.456	56 2/5 seconds	Spraying OK
		Glaze 745	Milled 8–31–1923	
8:00 A.M.	9–1	1.460	88 3/5 seconds	
7:30 A.M.	9–5	1.461	53 seconds	
12:15 P.M.	9–6	1.462	55 1/5 seconds	Spraying OK
		Glaze 745	Milled 9–30–1923	
12:15 P.M.	10–1	1.459	52 seconds	
10:45 A.M.	10–2	1.460	48 seconds	
Percentage of water in slip increased 0.31% by weight				
4:00 P.M.	10–4	1.456	45 seconds	Spraying OK

Such changes in the initial viscosity of the slip are probably due to differences in the amounts of soluble salts contained in the clays. These variations are best avoided by using three or more kinds of clay in making the slip, and by withdrawing each clay from a large supply which has been previously mixed as to render it practically homogeneous.[2]

[1] Robert Twells, Jr., "The Field of Porcelain Glazes Maturing between Cones 17 and 20," *Jour. Amer. Ceram. Soc.*, **5** [7], 430(1922). "Further Studies of Porcelain Glazes Maturing at High Temperatures," *ibid.*, **5** [11], 1113(1923).

[2] Robert Twells, Jr., "Handling and Storing Raw Materials to Produce Uniformity in a Body," *Ibid.*, **7** [2], 82(1924).

The use of several kinds of clay in making the slip has been found desirable for other reasons. Laboratory experiments have shown that different types of clays when used singly give glaze slips of widely different viscosities. Generally speaking, a glaze slip made with a ball clay has a low viscosity, one made with a Florida kaolin has a medium viscosity, and one made with North Carolina kaolin has a high viscosity. By combining several clays in the porportions determined by experiment, it has been found possible to avoid the use of electrolytes to a large extent in preparing the slip. It is also desirable to use several clays to fit the slip coating properly to the body. Cracking, peeling or dusting of the dry slip can thus be avoided.

(2) Storing the Glaze Slip

It formerly was the practice here to store the slip in one or two large storage tanks, each holding several mill charges. This method was never very successful. The slip in the tank was always an unknown mixture in different stages of aging. It usually would over-age before it could be used. The effect of aging a glaze slip is shown by Table II.

TABLE II

Tests taken		Specific gravity	Viscosity	Remarks
Time	Date	Glaze 787	Milled 1–11–1924	Tank No. 2
11:10 A.M.	1–12	1.465	100 seconds	
1:30 P.M.	1–14	1.465	52 seconds	
4:15 P.M.	1–15	1.466	46 seconds	
Percentage of water in slip increased 0.48% by weight				
7:30 A.M.	1–16	1.460	45 seconds	Spraying OK
1:00 P.M.	1–16	1.460	46 seconds	Spraying OK
4:15 P.M.	1–16	1.460	45 seconds	Spraying OK

As the slip is aged its viscosity falls. If it ages too long, an acid electrolyte must be used to raise the viscosity for spraying. This can be done, but usually it does not spray as well as a properly aged slip. On the other hand a newly made slip cannot be sprayed satisfactorily. This is no doubt due to the air bubbles which it contains. The correct length of aging the slip is probably from three to six days.

When the large slip storage tanks were abandoned for smaller ones, each holding one mill charge it was felt that this would solve many of the difficulties previously encountered. However, new troubles were met.

At first, after circulating through the supply pipes the slip was returned at the top instead of near the bottom of the storage tank. It thus fell with considerable force and carried a great many air bubbles into the slip remaining in the tank. For the same reason it was necessary to greatly reduce the agitation of the tanks and the speed of circulation of the slip in the supply line.

Another source of trouble was the lack of tops on the tanks. These were left uncovered to facilitate cleaning. It was soon found that the slip dried on the sides of the tank and kept dropping off. These pieces tended to clog the spraying nozzles. A more important effect on the lack of covers was on the temperature of the slip in the tanks. It was found very difficult to spray the slip when cold. When covers were put on the tanks, the heat, generated in the slip by friction, was held in the tanks, and the temperature became right for spraying. A typical record of the variations in the slip temperature are shown in Table III.

TABLE III

Tests taken		Specific gravity	Viscosity	Temperature	Remarks
Time	Date	Glaze 769	Tank No. 4	Milled 11–29–1923	
		Room Temperature 79°F			
7:15 A.M.	11–30	1.444	41 seconds	80°F	
4:15 P.M.	11–30	1.446	39 seconds	81°F	
		Slip Circulating in Supply Pipe			
7:15 A.M.	12–1	1.448	40 seconds	80°F	Spraying OK
11:10 A.M.	12–1	1.448	42 seconds	$89^{2}/_{10}$°F	Spraying OK
		Slip Remained over Week End Merely Being Agitated in Tank			
7:30 A.M.	12–3	1.451	42 seconds	84°F	Spraying OK
		Percentage of Water in Slip Increased 0.38% by Weight			
12:00 M.	12–3	...	....	88°F	Spraying OK
12:35 P.M.	12–3	1.446	$39^{2}/_{8}$ seconds	89°F	Spraying OK

As the slip circulates in the supply pipes its temperature rises rapidly. This results in a corresponding rise in the viscosity. In fact it is usually necessary as the slip warms up in circulating to add water to lower its viscosity in order to keep it spraying properly.

Other changes found necessary in practice were connections to admit compressed air and water to the slip circulation line for blowing and washing out at frequent intervals.

(3) Spraying the Glaze Slip

Obviously the slip must be atomized as uniformly as possible, or the nozzles could not be set to spray evenly to a given line on the cores. Thus the slip must flow evenly through a small orifice—not in lumps or clots. The air pressure for atomizing must be kept steady and at a definite pressure.

The guards must be easily adjusted and properly designed to assist in warding the spray off the portions to be left unglazed.

Direct connection of the nozzles with the circulation line was found undesirable because the pressure in the line is too high and irregular. A hopper is now used on each spraying machine to hold a small supply of slip. It was found necessary to install a combined agitator and lawn in these hoppers, in order to keep the slip uniform and free from lumps.

If the lines between the sprayed and unsprayed surfaces are not at the

same points on successive cores, the slip may be either too light or too heavy. If the slip tends to settle in the hoppers, if the unsprayed surfaces show a heavy coating of slip dust, and if the slip coating on the sprayed surfaces is not smooth and firm but is rough and spongy, the slip is too heavy, *i. e.*, it contains either too little water, too much acid electrolyte, or both. If the spray beads up irregularly on the core, and flows somewhat raggedly over the unsprayed surfaces, the slip is too light, *i. e.*, it contains either too much water, too much alkaline electrolyte or both. Where the equipment and operating conditions are normal, and the specific gravity of the slip is held within limits, it is usually safe to assume that trouble in spraying is due to the nature and amount of the soluble materials in the slip. Attempts to correct the spraying qualities of the slip with electrolyte while it is being used, has seldom been successful. This seems to make the slip spray even more irregularly for a time. The practice which has given the best results has been to mill the slip slightly heavier than required, and then to water it down gradually until it sprays satisfactorily. This makes use of the soluble salts already in the materials and avoids to a large extent further additions of electrolytes.

Summary

The rather difficult operation of spraying spark-plug cores has been made comparatively easy by the following factors:

(1) The design and construction of better equipment.

(2) More careful control of composition and homogeneity of the raw materials.

(3) Use of such a mixture of clays in making the glaze slip as to produce naturally the viscosity desired without further additions of electrolytes.

(4) Improved milling and aging of the slip.

(5) Handling the slip in batches, each consisting of one mill charge.

(6) Frequent specific gravity and viscosity tests of the slip as it is being aged and sprayed.

DETROIT, MICH.

Discussion

MR. FRITZ: Your viscosity is not always the same for spraying, is it?

MR. TWELLS: No. The specific gravity may be held fairly constant, but the viscosity has to be varied to meet new conditions as they arise. Fortunately, however, in every-day practice where the atmospheric conditions do not differ widely and there has been no change in raw materials, it is possible to hold the viscosity within fairly close limits and be sure of good results.

MR. MCAFEE: Are the viscosity determinations made under standard temperature conditions, or are the conditions constant enough in the plant? If the latter is the case, would you think it necessary, in a plant where the temperature varies considerably, to have a calibration with reference to temperature?

MR. TWELLS: We do not make our viscosity tests at a standard room temperature, and for our requirements we hardly think that it is necessary. We are interested in measuring the viscosity of the slip at its temperature in the tank, not at the room temperature. Consequently we take the slip from the tank and test it at once, before it has a chance to cool.

MR. FRITZ: We maintain a somewhat similar control of the glaze in our plant. We have found that it is necessary to keep the viscosity within certain limits and in doing this, the weight may vary considerably, since we do not always necessarily get the same weight for the same viscosity. We know, however, that if the viscosity is right, the glaze is fit for use, regardless of the weight, and our control is based entirely on this principle.

The variation in the relation of viscosity to weight, besides being due to the controllable factor of temperature and length of blunging is also dependent on the type of clay used and variations in any one type of clay. We cannot predict the latter, and adjustment is more for this factor after the clay has been run into the storage cistern from the mixing mill. It is often not necessary to make any adjustment whatever, for we have gone along for several weeks, with no change in the viscosity of the glaze, as it came from the mill. However, by checking each batch, the system is fool proof, and we have no difficulty in maintaining uniform glaze coatings.

THE PROBLEM OF HEAT ECONOMY IN THE CERAMIC INDUSTRY—II[1]

By Willi Cohn

Results of the Experiments

A. Tests with the Calorimeter

Thanks to the kindness of Professor Dr. Bauer, to whom acknowledgment is here made, it was possible to use the same test materials which had already been used by Heyn, Bauer and Wetzel.[2] Numerous kinds of fire clays had been investigated by them, both as to thermal conductivity and as to specific heat. These investigations were made at temperatures up to 1200°C. They had determined specific heat in the usual way calorimetrically by the method of mixtures.

As reference substance we selected fired fire-clay body "4." From the values of specific heat under various temperatures, as indicated by Heyn, etc., we calculated the q-t curve; compare Fig. 23, where also the values of the mean and the true specific heats, c_m and c_w, are given. This figure also shows the graphic determination of c_w and c_m from a given initial temperature.

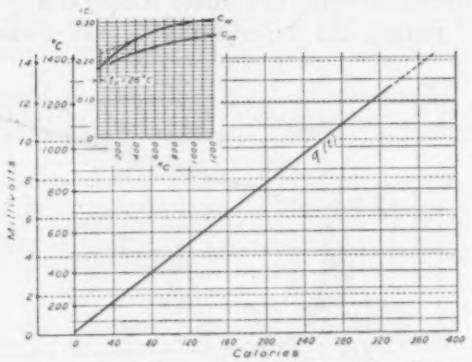

Fig. 23.—Fired fire-clay body "4" used by Heyn, Bauer and Wetzel.

In these tests the readings of the temperature were in millivolts; consequently temperature on the q-t curve is also indicated in millivolts. A curve of this sort is given in Fig. 23*a*. It will be seen that it is not a straight line, consequently the standard measure of temperature (°C) in Fig. 23 is not a *uniform* one. The curve of specific heat in Fig. 23 shows that

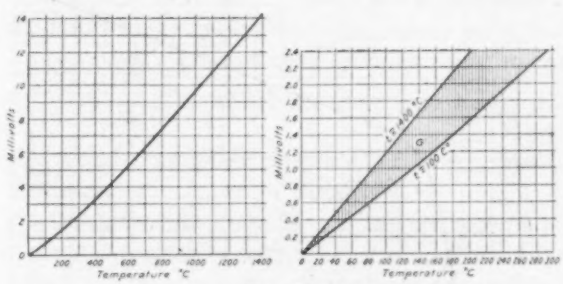

Fig. 23*a*.

[1] For Part I of this paper see *Jour. Amer. Ceram. Soc.*, **7** [5], 359(1924).

[2] Heyn, Bauer and Wetzel, "Untersuchungen über die Wärmeleitfähigkeit feuerfester Baustoffe," Mitteil. aus d. Königl. Materialprüfungsamt, 1914, 213.

specific heat is variable with temperature; hence it is to be expected that the q-t curve calculated on the basis of specific heat will also result in a curved line.

On the chart which indicates temperature in millivolts both curvatures accidentally cancel each other so that the q-t curve for this substance appears as an almost straight line.

B. Preparing the Curve Chart

Fig. 24 has been made for the reference material body "4." By reason of the great exactness of the measurements—obtainable by the differential method employed—it is possible to indicate G in proportion of 5:1 as compared with the furnace temperature.

During the experiments G was measured in millivolts.

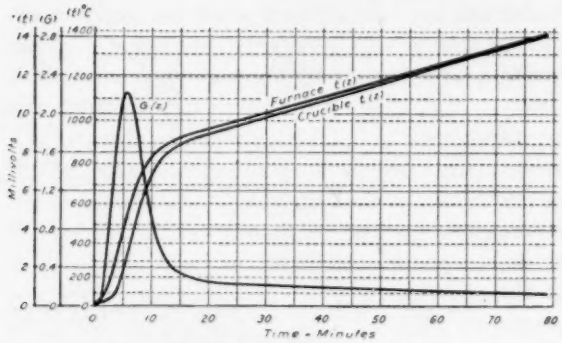

FIG. 24.—Fired fire-clay body "4".

In contradistinction to temperature t which was also determined in millivolts, it is not feasible to read the extent of temperature differences between furnace wall and crucible directly from the calibration of the thermoelements in terms of degrees. Let us suppose the furnace wall has a temperature of 375°C corresponding to 3.0 millivolts, and the substance has 263°C, corresponding to 2.0 millivolts; the difference then is 112°C, corresponding to a difference in the reading of 1.0 millivolt. If the temperature of the furnace wall is 1292°C, corresponding to 13.0 millivolts, and the substance is 1207°C, corresponding to 12.0 millivolts, the difference in temperature would then be 85°C, while the difference in reading, as in the preceding case, is 1.0 millivolt.

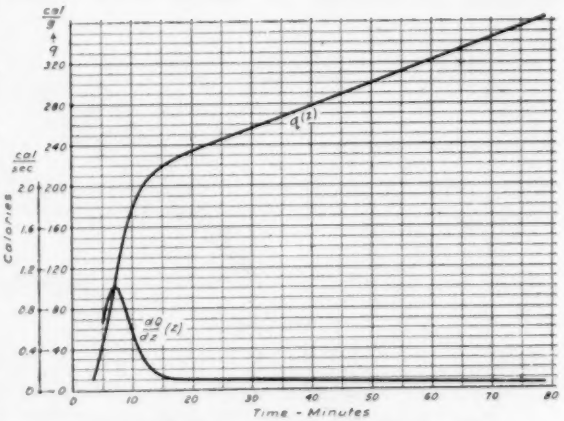

FIG. 25.—Q = two grams.

Fig. 23*a* gives a shaded area within which the values of G, expressed in °C are located, corresponding to a definite value of G, expressed in millivolts.

From this test resulted directly the t-z curve for the furnace, as well as the G-curve. From these two we obtained, by subtraction, the t-(z) curve for the crucible material. The q-(t) curve, together with the t-(z) curve, was combined into the q-(z) curve. (In Fig. 25.)

The curve, considered as a *furnace characteristic* is *independent* of the nature of the test material; it represents the *total* flow of heat used for G and t. The quantity of heat q refers to 1 g. of the substance and is measured in cal./g. Our test arrangements provided for 2 g. of the substance.

The amount of heat requisite for heating 2 g. of substance, which was actually measured during our test, is hereafter indicated as Q. The following relation thus exists between Q and q:

$$Q = 2q$$

In this connection q is measured in cal./g; Q in cal., since "2" represents the weight in grams.

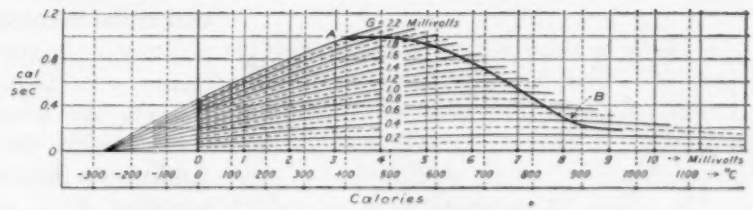

FIG. 26.—Furnace characteristic.

The differentiation of the q-(z) curve (carried out according to Sanden[1]) and the doubling of its values gives us the $\frac{dQ}{dz}(z)$ curve needed for preparing the curve chart; this is also indicated in Fig. 25.

Numerous temperature-time curves were made with the reference material body "4," and then calculated in the manner described. Next all $\frac{dQ}{dz}(z)$ curves with the aid of the $t(z)$ curves were drawn as $\frac{dQ}{dz}(t)$ curves. By combining those points which had a like G we obtained the furnace characteristic shown in Fig. 26.

We have drawn into the furnace characteristic, as an example, the values of the curve for fire-clay body "4" in Figs. 24 and 25 (Curve A-B, Fig. 26, for the sake of clearness a part only of the descending branch of the curve has been indicated).

The checking up of the curve chart was done by comparing the results obtained with known values; further details are referred to under quartz,

[1] H. v. Sanden, "Praktische Mathematik," Berlin, Urban (1920).

cristobalite and fired fire-clay, which had already been tested by Heyn, Bauer and Wetzel.[1]

C. Determining the q-t Curves

To determine the q-t curves from the furnace characteristic we selected Zettlitz kaolin for the experiment; the results appear in Figs. 27 to 29.

Several temperature-time curves (at varying rates of speed during heating) were made for this material. Fig. 27 represents such a curve on a small scale. With the aid of the furnace characteristic we then developed the $\frac{dQ}{dz} - (z)$ curves.

The determination of the q-z curve was made on the basis of the following:

$$q = \int dq = \int \left(\frac{dq}{dz}\right) dz = {}^1/_2 \int \left(\frac{dQ}{dz}\right) dz$$

The two last-named curves have been drawn in Fig. 28. The integration constant, however, has not been considered; it results on the supposition that at the initial temperature of the experiment $q = 0$. In other respects the integration constant has no influence on the determination of c_w, since $c_w = dq/dt$ is independent of the absolute value of the function $q(t)$.

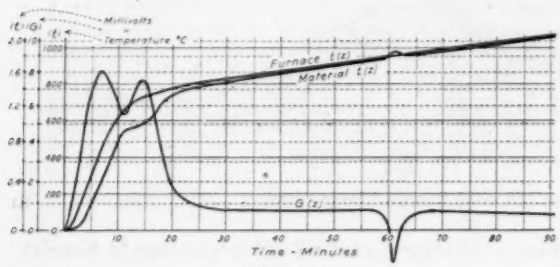

FIG. 27.

Combining the q-z and the t-z curves gives the desired q-t curve from which the desired values can be determined directly, according to Fig. 29.

Zettlitz Kaolin

Temperature-time curve of Zettlitz kaolin (clay substance 98.5%) shows several reactions. These appear particularly sharp on the G-z curve by reason of the considerably enlarged scale (in Fig. 27). The same reactions may also be clearly seen on the q-t curve.

The heating curves show that the degree of temperature at which a certain reaction takes place is independent of the rate of heating. All temperature-time curves have the same q-t curves. The q-t curves determined from various temperature-time curves varied at the most by $\pm 3\%$.

[1] *Loc. cit.*

1. Endothermal Reaction

On the temperature-time curve there appears clearly the splitting off of chemically combined water. This attained its maximum at about 575°C. The heat consumption of this endothermal reaction, on the q-t curve, shows 91.8 ± 3 cal./g.

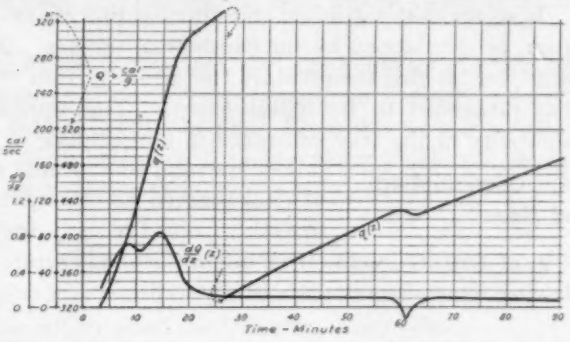

FIG. 28.—Development of q-t curves, unfired Zettlitz kaolin $Q = 2$ g.

Fig. 29 shows how this value has been determined. Such endothermal reactions scarcely ever present exactly horizontal curve sections hence the curve lines above and below the reaction in question must be extrapolated as is done in our figures.

2. Exothermal Reaction

An exothermal process appears at about 950°C, the chemical significance of which is not yet fully clear. It is now generally assumed that a combination of Al_2O_3 and amorphous SiO_2 is involved. On the q-t curve up to this point the temperature rises fairly regularly with the inducted heat. Then appears a sudden rise in temperature of nearly 50°C as a result of the exothermal reaction in the mass. The loss of heat then becomes so considerable that q declines and the temperature falls. After that again begins an increase in temperature with the inducted heat. In this manner originates the loop on the q-t curve.

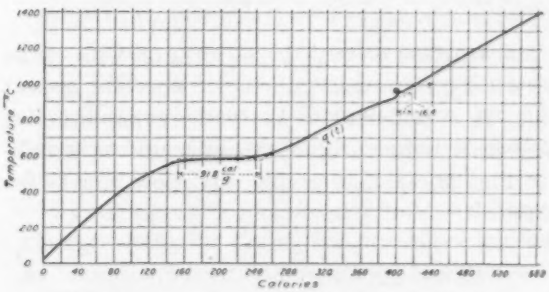

FIG. 29.—q-t curve for unfired Zettlitz kaolin.

The extent of the exothermal reaction is obtained by extrapolation of the lower curve sections up to that point of the temperature from which the rise is steadily upwards. See Fig. 29. The extent of the heat changes so occurring is: -16.4 ± 0.5 cal./g.

3. Further Reactions

Before the exothermal process the G-z curve shows a rise similar to that in an endothermal process. During this the temperature of the substance remains below that of the furnace. In consequence G is in-

creased. From about 650°C on to the temperature of the exothermal process, the q-t curve declines more than is expected from the remaining curve sections.

It seems that a gradual endothermal process takes place which may, in part, be overlapped by the exothermal process. At any rate it is noticeable that at this temperature the disintegration of the kaolinite molecule has proceeded to its fullest extent. This appears also from the high solubility of the clay substance in hydrochloric acid at this temperature.

4. Consumption of Heat The consumption of heat at a given temperature, of vital concern for the industry, can be determined directly from the q-t curve. In order to heat 1 g. of Zettlitz kaolin from an initial temperature of 20°C up to the following temperatures there is required:[1]

Temp. °C	100	200	300	400	500	600	700
Cal.	16.1	36.7	59.6	85.7	119.4	240.5	292.5
Temp. °C	800	900	1000	1100	1200	1300	1400
Cal.	332.6	385.9	420.4	454.8	488.8	524.6	560.3

5. Specific Heat From the values of the q-t curve the mean specific heat is found according to the formula $q = c_m(t-t_0)$. For an initial temperature of $t_0 = 20$°C we find from the above values:[1]

Temp. °C	100	200	300	400	500
c_m	0.201	0.203	0.213	0.226	0.249

As soon as the endothermal reaction occurs, the mean (and with it the true) specific heat assumes wholly abnormal values. It does not appear necessary to indicate them. It is sufficient to know the expenditure of heat necessary to attain a certain temperature; this expenditure is indicated above. According to Fig. 23 one may graphically show how to determine actual specific heat.[1]

China Clay

As a second representative of clay materials we tested china clay containing 97.5% of clay substance. The reactions occurring on the temperature-time curve as well as those on the temperature-heat curve were the same as for Zettlitz kaolin and differ but slightly from the latter.

1. Endothermal Reaction. This reaction appeared most noticeably at about 575°C. It amounts to 92.6 ± 3 cal./g.

[1] These data are repeated, together with similar data for all the other substances investigated, in Tables I and II.

2. Exothermal Reaction. At a temperature of 950°C the q-t curve showed the same loop as indicated for Zettlitz kaolin. The value determined was -16.0 ± 0.5 cal./g.

The consumption of heat and the specific heat will be found in Tables I and II.

From the numerical values it appeared that the behavior of china clay during heating not only qualitatively but also quantitatively coincided to a high degree with that of Zettlitz kaolin. From this we may conclude that the behavior of other kaolins will yield values which will deviate but slightly from the values here given.

Pure Clay Substance

By recalculating the values found for Zettlitz kaolin and china clay over to a pure clay substance we obtained the following mean values:

1. Endothermal Reaction. For the splitting off of water in chemical combination in pure (100%) clay substance, is required: 94.0 ± 3 cal./g.

2. Exothermal Reaction. The amount of heat set free by the reaction at about 950°C is -16.5 ± 0.5 cal./g.

These values were made the basis for the subsequent calculations of heat-changes of ceramic materials.

Previous Investigations

Mellor and Holdcroft[1] investigated the constitution of the kaolin molecule, and, among other things, also made heating curves. They made use of the following testing-device:

The test-substance was contained in a crucible which had been placed into another crucible; the space between the two having been filled with sand. The two were then heated over a Bunsen burner. With the aid of a thermoelement in the substance and another in the sand filling—to serve for checking purposes—the temperature-time curves were then made.

By some graphic method, not indicated, they determined values for heat-changes occurring during the heating of kaolinite. They designated them as "rough approximations not without grave errors."

They obtained the following results: For the endothermal process at 575°C: 42 cal./g; for the exothermal process at 950°C: -21.5 cal./g. Because of the testing device, these values can scarcely lay claim to accuracy.

D. Tschernobaeff[2] by heating in a bomb obtained 112 cal./g. This value, however, includes the values for all the reactions which occur be-

[1] Mellor and Holdcroft, *loc. cit.*

[2] *Rev. Met.*, 729, 1905.

TABLE I

Material	Heat needed in gram-calories to heat materials from 20°C to														Quantity of heat in gram-calories		
	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400°C	Endothermal reaction	Exothermal reaction	Heat of conversion
Zettlitz kaolin	16.1	36.7	59.6	85.7	119.4	240.5	292.5	332.6	385.9	420.4	454.8	488.8	524.6	560.3	91.8	−16.4	...
China clay	16.0	36.4	59.5	85.8	118.9	241.5	297.8	330.6	386.6	421.1	454.4	490.8	526.1	561.9	92.6	−16.0	...
Amorphous clay	15.9	36.3	60.4	86.1	115.1	144.8	175.5	209.3	244.3	298.9	...	...	...	...	....	....	...
Artificial corundum	16.3	37.9	62.4	87.7	116.2	145.2	176.1	212.2	252.3	297.6	...	...	...	...	....	....	...
Sillimanite, artificial	12.9	28.9	45.6	63.4	81.5	100.2	118.2	135.6	153.2	171.5	211.3	235.3	259.4	282.4	....	−19.9	...
Feldspar	12.9	29.1	47.1	67.8	91.7	116.7	143.4	172.1	201.9	240.5	281.2	309.7	...	...	....	....	...
Norwegian quartz	15.2	37.1	60.9	86.5	114.9	148.3	174.7	202.7	231.3	262.0	...	...	...	...	....	....	4.2
Rose quartz	15.2	36.8	60.2	85.9	114.8	148.1	174.3	202.3	231.0	261.7	...	...	...	...	....	....	4.1
Sand from Hohenbocka	15.2	36.8	60.1	84.5	112.0	145.2	173.2	201.0	230.5	261.5	...	...	...	...	....	....	4.1
Amorphous silicic acid	17.1	40.3	66.0	93.2	122.0	151.0	180.1	209.5	239.5	272.0	...	...	...	...	....	....	...
Cristobalite	15.5	38.0	66.2	90.3	117.1	144.0	170.3	199.7	228.7	259.9	...	...	...	...	....	....	6.0
Chalcedony	13.3	31.0	48.8	67.4	88.8	109.7	131.1	154.1	178.4	206.0	236.2	...	...	...	....	....	...
Porcelain, green	14.8	33.6	55.2	80.9	109.0	192.8	220.1	248.4	285.6	330.8	379.5	428.4	477.5	527.7	53.1	− 8.8	...
Porcelain, fired	15.1	35.1	57.0	80.2	106.8	134.6	166.7	205.8	252.9	307.8	363.9	...	...	...	....	....	...
Porcelain glaze, green	13.6	31.3	51.2	73.2	100.0	143.1	162.2	202.4	244.4	274.8	313.8	352.9	393.3	403.0	16.4	−12.3	...
Porcelain glaze, fired	14.3	32.6	52.9	74.7	95.8	117.0	159.0	164.0	192.1	226.3	265.0	...	....	...	....	....	...
Stoneware, green	14.5	33.0	53.8	76.1	103.3	168.5	196.0	218.4	247.0	283.8	335.4	387.6	440.7	...	48.9	− 7.9	...
Stoneware, fired	14.9	34.6	56.9	80.4	106.6	124.8	187.2	193.7	259.0	300.6	351.1	...	...	...	1.7	....	...
Chamotte, green	15.3	34.9	56.2	80.0	111.8	201.4	225.6	242.8	283.3	336.1	394.1	452.6	512.9	571.7	81.2	−13.8	...
Chamotte, fired	15.8	36.4	59.5	83.6	110.6	138.2	166.2	195.6	228.3	270.7	311.3	...	...	...	....	....	...
Chamotte "BC," fired	15.9	38.7	63.4	88.9	114.6	140.7	168.6	196.2	227.6	256.3	286.4	315.0	347.1	379.0	....	....	...
Halle clay, green	15.1	35.2	59.0	84.9	118.2	202.7	234.3	258.3	284.1	337.5	387.4	436.4	...	...	62.2	−11.9	...

TABLE II

Material	Average specific heat in mean calories between 20°C and 100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400°C
Zettlitz kaolin	0.201	0.203	0.213	0.226	0.249	*	...	...	...	...	...	...	...	...
China clay	0.200	0.202	0.213	0.226	0.248	*	...	...	...	...	...	...	...	...
Amorphous clay	0.199	0.202	0.216	0.227	0.240	0.250	0.258	0.268	0.278	0.305	...	...	...	...
Artificial corundum	0.203	0.211	0.223	0.231	0.242	0.251	0.259	0.272	0.287	0.304	...	...	...	...
Sillimanite, artificial	0.161	0.161	0.163	0.167	0.170	0.173	0.174	0.175	*	...	...	...	...	...
Feldspar	0.161	0.162	0.168	0.179	0.191	0.202	0.211	0.222	0.229	0.246	0.260	0.262	...	...
Norwegian quartz	0.190	0.206	0.217	0.228	0.239	0.256	0.257	0.260	0.263	0.267	...	...	...	...
Rose quartz	0.190	0.205	0.215	0.226	0.239	0.256	0.257	0.259	0.262	0.267	...	...	...	...
Sand from Hohenbocka	0.190	0.205	0.214	0.223	0.233	0.251	0.254	0.257	0.262	0.267	...	...	...	...
Amorphous silicic acid	0.214	0.224	0.236	0.246	0.254	0.260	0.265	0.269	0.272	0.277	...	...	...	...
Cristobalite	0.194	0.212	0.237	0.238	0.244	0.248	0.252	0.257	0.261	0.266	...	...	...	...
Chalcedony	0.167	0.172	0.175	0.177	0.185	0.189	0.193	0.198	0.203	0.210	0.218	...	...	...
Porcelain, green	0.185	0.187	0.197	0.213	0.228	*	...	...	...	...	...	...	...	...
Porcelain, fired	0.189	0.195	0.203	0.212	0.222	0.232	0.245	0.234	0.287	0.304	0.337	...	...	...
Porcelain glaze, green	0.170	0.174	0.183	0.193	0.208	*	...	...	...	...	...	...	...	...
Porcelain glaze, fired	0.179	0.181	0.189	0.197	0.199	0.202	0.204	0.211	0.218	0.230	0.245	...	...	...
Stoneware, green	0.181	0.183	0.192	0.201	0.215	*	...	...	...	...	...	...	...	...
Stoneware, fired	0.186	0.192	0.203	0.212	0.223	0.234	0.275	0.286	0.296	0.307	0.324	...	...	...
Halle clay, green	0.189	0.195	0.211	0.223	0.247	*	...	...	...	...	...	...	...	...
Chamotte, green	0.191	0.194	0.201	0.211	0.232	*	...	...	...	...	...	...	...	...
Chamotte, fired	0.197	0.202	0.213	0.220	0.231	0.238	0.244	0.251	0.230	0.277	0.288	...	...	...
Chamotte "BC" fired	0.199	0.215	0.227	0.233	0.239	0.243	0.248	0.252	0.258	0.261	0.264	0.267	0.271	0.274

*The quantities of heat necessary to attain higher temperatures may be obtained from Table I.

tween 20° and 1300°C. Consequently no conclusions can be drawn from this as to the values for the several reactions.

Knote[1] in a brief article, reports some tests for determining the specific heat of clays by means of an Emerson calorimeter. (Mixing method.) The clays tested by him were of the following composition (unfortunately he gives only the total analysis): SiO_2 53.30%, Al_2O_3 30.88, Fe_2O_3 0.71, CaO 0.50, MgO 0.08, TiO_2 2.21, alkalies 0.12, loss on ignition 12.24. The values of specific heat found by this author are: (between 22° and 150°C), raw 0.237, calcined at 650°C 0.204, at 1050°C 0.200.

In these values it is striking that in contrast with all other measurements of specific heat of bodies of similar composition, and especially of minerals,[2] the specific heat of a modification stable at a high temperature is less than that of a modification stable at a lower temperature.

From the values reported in the course of the present investigation, and compiled in Table II, it can be seen that the materials in use in ceramics have a higher specific heat in their fired state than in the unfired.

This behavior is paralleled by Van't Hoff-Thompson's law according to which the modification of a body, stable at high temperature, has a higher specific heat than the modification which is stable at low temperature.

Amorphous Alumina

Amorphous alumina was obtained by heating precipitated aluminum hydrate. The heating curve of this substance—in contradistinction to amorphous alumina obtained from aluminum nitrate—showed no reactions. Also the *q-t* curve showed no reactions. The values determined from this curve are given in Tables I and II.

The values obtained below the temperature of dehydration coincide closely with the results obtained with Zettlitz kaolin and china clay.

Artificial Corundum

With artificial corundum (molten alumina) no reactions appeared on the heating curve. The curves ran absolutely uniform and showed the values given in Tables I and II. These values, in agreement with the previously mentioned principle, were higher than those of unfired material.

Sillimanite

Sillimanite $Al_2O_3.SiO_2$ (amorphous) prepared in an electric arc[3] yielded the following results during heating (Fig. 30).

---

[1] Knote, "Note on the Specific Heat of Clay," *Trans. Amer. Ceram. Soc.* (1912); Ref. *Silikat-Zeitschrift* (1914).

[2] W. P. White, "Specific Heat Determination at Higher Temperatures," *Am. J. Sci.*, **47** (1919); Ref. *Phys. Ber.*, **13** (1920).

[3] Kindly furnished me by Mr. Blei, a student in chemistry at the Chemo-Technical Experiment Station of the Government Porcelain Factory at Berlin.

1. Exothermal Reaction. At about 950°C an exothermal reaction occurred, the cause of which cannot be stated as yet. The amount of heat liberated was -19.9 ± 0.6 cal./g.

2. Other Reactions. In agreement with the formula given above, no splitting off of water in chemical combination took place. On the other hand, there was a noticeable gradually continuing endothermal process below the exothermal reaction.

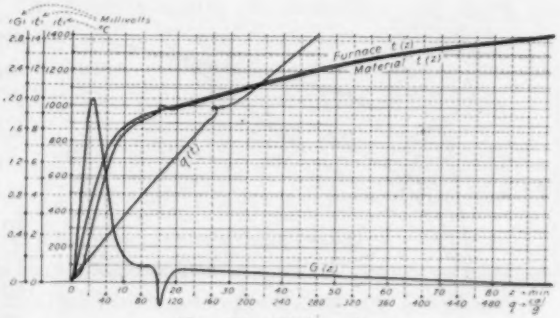

FIG. 30.—Sillimanite.

The steep rise of the *q-t* curve in itself points to the fact that the specific heat is unusually low. The data are included in Tables I and II.

Feldspar

The curves obtained for very pure Norwegian potash feldspar ran uniform throughout showing no reactions whatever. From about 1100°C the *q-t* curve is quite flat. This means an increase of the apparent specific heat; probably due to an incipient fusion. This, according to Nacken[1] sets in at about 1200°C.

The several results are included in Tables I and II.

Quartz

In order to get a survey of the various modifications of quartz as they occur in nature, the following materials were submitted to tests: (1) Crystalline silica (Norwegian quartz, rose quartz, Hohenbocka sand); (2) amorphous silica; (3) cristobalite; (4) chalcedony.

Norwegian Quartz The temperature-time curve clearly showed the transformation of α-quartz into β-quartz occurring at 575°C. This was clearly observed on a curve made at a slow rate of heating. The temperature-time curves required for the higher temperatures and taken with a greater speed in heating, of course, also show this reaction.

The *q-t* curves determined from the *t-z* curves agreed well with each other, in consonance with the other test-materials. Fig. 31 shows a *t-z* curve made at a slow rate of heating, as well as a portion of a curve made at greater speed. It also shows the *q-t* curve developed from these.

[1] R. Nacken, *loc. cit.*

The transformation of quartz to tridymite cannot be observed on these curves because this transformation is so extremely slow.

The following values resulted in detail:

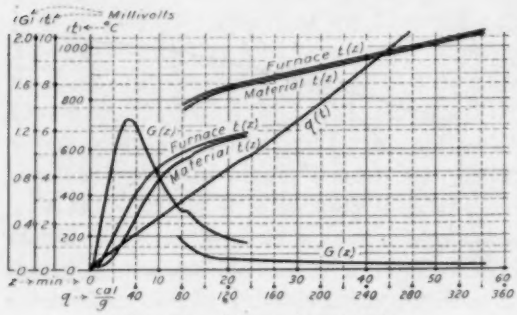

FIG. 31.—Norwegian quartz.

1. Heat of Transformation. The transformation of α-quartz into β-quartz occurring at 575°C is an endothermal reaction. The value of this reaction determined from the q-t curve is 4.2 ± 0.2 cal./g. The consumption of heat and the specific heat are given in Tables I and II.

Rose Quartz

In order to study the behavior of crystalline silica in another substance we tested some very pure rose quartz which had been placed at our disposal by Professor Tannhäuser. It reacted very much like Norwegian quartz.

Hohenbocka Sand

This has a silicon dioxide content of 99.95%. It finds extensive use in ceramic industries. The heating curve showed the course typical for all kinds of quartz.

From the numerical values given in Tables I and II it can be seen that the results from these three crystalline silicas show a fairly close agreement. In the following we shall take up the results which have been obtained previously.

Previous Tests

1. Heat of Transformation

The only reference to heat-changes in the transformation of quartz is by White and is referred to by Wright and Larsen.[1] His value of this transformation heat is 4.3 ± 1 cal./g.

This agrees well with our results although obtained by a graphic method.

From the values of specific heat established by White we can graphically determine the heat changes at 575°C with the aid of the formula $q = c_m(t-t_0)$. Where the specific heat is known, it is possible to calculate the quantity of heat at the various temperatures. If we employ q as a function of t, the curve resulting will be uniform, showing a break only at a

[1] F. E. Wright and E. S. Larsen, "Quarz als geologisches Thermometer," *Am. J. Sci.*, **27** (1909); *Z. f. anorg. Chem.*, **68** (1910).

temperature of 575°C. By extrapolating the curve below and above the transformation temperature any heat change occurring during the reaction is determined.

2. Specific Heat A large number of investigations have been made. White[1] investigated up to high temperatures by the method of mixtures. The values determined by him (mean specific heat between 0°C and higher temperatures) are as follows:

Temp. °C	100	300	500	700	900	1100
c_m	0.1868	0.2168	0.2381	0.2543	0.2595	0.2684

These values coincide very well with those found by us.

Schulz[2] also used a water calorimeter. The values found by him (mean specific heat between 20°C and higher temperatures) are as follows:

Temp. °C	100	250	410
c_m	0.1871	0.2086	0.2253

These figures also agree well with ours.

See Schulz[2] for a condensed survey of experimental results with quartz by various investigators.

After having determined the values for crystalline silicon dioxide we studied the behavior of amorphous silicon dioxide during heating.

Amorphous Silicon Dioxide

By moderate ignition of silicic acid at about 700°C amorphous silica was prepared. The heating curves obtained show a uniform course throughout. No reactions of any sort were noticeable. The results are contained in Tables I and II.

Cristobalite

Cristobalite prepared from "flint" showed very clearly, under sufficiently slow heating, the transformation of the α to the β modification. Further transformations could not be observed.

The transformation of α cristobalite into β cristobalite occurred at 235°C. From the q-t curve the consumption of heat for the endothermal process was 6.0 ± 0.2 cal./g. The consumption of heat and the specific heat are given in Tables I and II.

Cristobalite being the modification which is stable at the higher temperature has a specific heat greater than crystalline silica.

The mean specific heat of cristobalite found by White by calorimetric

[1] W. P. White, *loc. cit.*

[2] K. Schulz, "Über die mittlere spezifische Wärme von Quarz und Quarzglas in drei verschiedenen Temperaturbereichen," *Centralbl. f. Min. usw.* (1912).

tests and the method of mixtures at different temperatures from 0°C were:

Temp. °C	100	300	500	700	900	1100	1300	1400
c_m	0.1882	0.2332	0.2425	0.2508	0.2568	0.2625	0.2662	0.2680

These values show good agreement with the results we have obtained.

Chalcedony

A large number of heating curves were made at various speeds of heating. In agreement with Fenner[1] there appeared no reaction whatever on these curves. Laschenko, whose findings are referred to by Rieke,[2] claimed to have found a heat-change in chalcedony at 230°C. Such a reaction in no case appeared during our tests.

The temperature-time curve and the temperature-heat curve appeared uniform throughout and showed values given in Tables I and II.

(To be continued)

[1] C. N. Fenner, "Die Stabilitätsbeziehungen der Kieselsäuremineralien," *Z. f. anorg. Chem.*, **85** (1914).

[2] R. Rieke, "Neure Fortschritte auf dem Gebeit der keramischen Chemie," *Fortschr. d. Ch. usw.*, **6** (1912).

GLOSS GLAZES AND INDIAN DESIGNS ON NORTH DAKOTA POTTERY[1]

By Margaret Cable[2]

Introduction

The problem outlined below was carried out by students in the Ceramic Department of the University of North Dakota. The students to whom this particular problem was presented derived much real pleasure and profit, not only in the actual execution and possession of the pieces made, but also in the study of Indian pottery necessary in their search for suitable design material.

The problem was to make and decorate a suitable form with a design more or less typical of Indian pottery, the design itself to be carried out in colored gloss glazes while the warm background tone of the whole was to be accomplished by a thin spray of glaze of harmonious color.

No attempt was made to merely imitate Indian pottery or to make use of Indian methods or processes of decoration. Colors generally foreign to these wares such as green and blue were freely used, the idea being simply that the bold beautiful patterns seen on many of the best examples of Indian pottery afforded a fruitful study and presented a rich field of design which could be adapted and translated for modern ceramic work.

The floating on or inlaying of colored glazes is, of course, an ancient process, nor is there anything new in the use of Indian motifs for pottery decoration, but the two ideas have not been combined with just the same results as were obtained in this particular instance.

Source of Design Material

The inspiration and design material was drawn entirely from books. The Annual Report of the Smithsonian Institution for the years 1901 and 1902 proved very helpful, as did the Reports of the Bureau of Ethnology for the years 1882–83 and 1895–96. These reports, especially the latter, contain many beautiful colored plates and much interesting and instructive descriptive matter. There are available, of course, many magazine articles and books on primitive and Indian pottery and basketry.

After the student had become familiar with the contents of these volumes and had absorbed something of the rhythm, the boldness and the beauty of Indian design, the actual work of carrying out the design on the piece itself was begun.

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[1] Presented at the Atlantic City Meeting, Feb., 1924 (Art Division).

[2] Assistant Professor of Ceramics, University of North Dakota, Grand Forks, North Dakota.

Selection of Form

As the aim was not to copy Indian pottery, but to use modern methods and glazes in the production of a pleasing and artistic product with a flavor of Indian about it, we did not feel that it was essential to adhere entirely to typical Indian shapes which are apt to be rather too rounding on the bottom for the present day comfort and stability. We selected, rather in the main, low full curved bowls with fairly broad substantial bases.

The forms themselves may be built, thrown or cast at the convenience of the worker. We used the latter method for the reason that there had

been made previously by this group of students several molds, the shapes of which were well adapted to this particular need.

Body

A light colored body is essential if the transparent gloss glazes given later are employed. Entirely different color effects would result if these glazes were applied to a red body, for example. A porous body of a light cream color was used in these pieces, as the high grade potter's clays of North Dakota, on which our research work is being done in the Ceramic Department of the University, burn to an ivory or light cream color.

Outlining Design

After the vessels were cast, dressed down and dried, the designs, carefully drawn and fitted to the space, were traced upon the green ware. A suitable underglaze color, preferably dark brown or black was then mixed with a little dissolved gum arabic and water to a consistency which flowed easily from the brush, and the outline was painted in with the underglaze color using a fairly bold, broad brush line. The pots were then biscuited and the work of filling in the various units of the design with colored gloss glazes was begun.

Selection of Colors

It seemed more in keeping with the style and the type of decoration to limit the colors used in the design itself to two or possibly three colors, as it was felt that, inasmuch as the designs were bold and simple, they should

be carried out with a corresponding simplicity of color arrangement. Blue and brown were combined with perhaps a touch of green or brownish black and green, with a suggestion of red.

The background color decided upon, a warm orange brown and buff, was practically the same for all the pieces and was obtained by spraying on with the air brush a thin glaze coat of these two colors which permitted the light cream clay body to show through the orange brown, giving thereby a suggestion of the shading and warmth of real Indian wares.

The Glaze

The following table gives the composition of the glaze. Gloss transparent, cone 2–3.

	Blue	Green	Black	Buff	Brown	Orange	Red
White lead	51.50	40.5	51.50	73	73	73	73
Zinc oxide	17.50	17.50	17.50	17.50	17.50	17.50	17.50
Whiting	29.0	29.0	29	29	29	29	29

	Blue	Green	Black	Buff	Brown	Orange	Red
Feldspar	116	116	116	116	116	116	116
Kaolin	58.50	58.50	58.50	58.50	58.50	58.50	58.50
Flint	35	35	35	35	35	35	35
Cobalt Carbonate	9.9	...	...	...	...	...	...
Black oxide cobalt	...	2	...	...	...	...	...
Black oxide copper	...	8	...	...	...	...	...
Best black underglaze	...	...	9	...	...	...	...
Cobalt carbonate	...	...	9.9	...	...	...	...
Brown underglaze 228	...	...	...	5.28	...	...	...
Brown underglaze 228	...	...	...	...	25	...	...
Light brown underglaze	...	...	...	...	...	25	...
Pink oxide	...	...	...	...	...	...	50

Each of the above glazes were ground $1^1/_2$ hours in a ball mill. A tablespoonful of a thin gum arabic solution was added and the batch brushed through a hundred-mesh screen. This glaze remains stationary in the fire and will not run unless greatly overfired or unless applied much too thick.

The best results were obtained with a glaze thickness of $^1/_{32}$ to $^1/_{16}$ of an inch, and fired to cone 2 to 3.

Filling in Design

Upon merging from the biscuit kiln the design outlined in the fired underglaze color was filled in with colored glazes. The thin glaze was applied to the porous biscuit with a medium size sable brush.

It was found better to float the glaze on in two or three thin coats rather than to attempt to build up the proper thickness in one application. In this way thick and thin places in the glaze were reduced to a minimum.

The spaces to be filled in with glaze should not be too large as it is difficult to maintain an even coating over a large area. It was also found best to build up one space at a time to the right thickness ($^1/_{32}$ to $^1/_{16}$), before proceeding to the next. Care should be taken to maintain this thickness right up to the flat outline of underglaze color.

The Background Glaze

After the various parts of the decoration were carefully filled in with glaze to the desired thickness the piece was set upon a whirler and a very

thin coat of buff and orange brown glazes were sprayed upon it. The buff was first sprayed over the whole piece and the orange brown was then blended in principally at the top and bottom to obtain a shaded effect. Care was taken to keep this background glaze quite thin, especially over that portion occupied by the pattern, much of which was filled in with glaze.

The Fire

The glazed wares were fired in an oil burning muffle kiln of the usual type, to cone 3, for a period of 12 to 14 hours.

I have hesitated to use the word inlay in the description of this problem for the reason that it is not strictly an inlay process, since the whole background of the piece is applied with the air brush and is superimposed over the filled-in design.

The difficulties were lessened when the underglaze outline was used, as described, to separate and define the various parts of the pattern; but it was found that this flat outline could be used or not as desired. The results obtained in the pieces where no outline was used were perhaps the more pleasing. There was little trouble experienced in keeping the glaze within the space allotted it on a flat or vertical surface, whether with or without an outline if proper care was taken to keep the thickness as indicated and if the glaze was not overfired.

When no underglaze outline was used the edges of the design were not quite as sharply cut and hard looking, they were softer and more elusive, although still clearly defined and with no evidence of spreading into each other or the background glaze.

The background glaze being sprayed over the whole modifies somewhat the colors used in the raised parts of the design but this serves to blend and harmonize the colors with each other and the background, and ties them all up together.

This little problem presents no undue difficulties to the student capable of making and applying glazes. If the directions given are carefully followed the result should be an attractive bit of pottery and a renewed appreciation and respect for those early American potters, the Red Men.

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THE USE OF GELATINE IN GLAZE APPLICATION[1]

By Albert C. Gerber

ABSTRACT

Painting with gelatinized glaze offers distinct advantages. A high grade hide gelatine should be used, and careful regulation maintained in all steps of the process. High clay mixtures gelatinize with greater difficulty than those whose contents of ground material are large. Loss from rubbing or chipping of glaze becomes a minimum.

A method of glaze application which despite some rather interesting aspects as well as commendable features, has attracted little attention in the ceramic industry at large, is that of painting the glaze after it has been mixed with a gelatine solution and chilled. In sanitary ware plants employing fire-clay bodies, this method of glazing has been common procedure for many years and is fairly well understood, and in occasional plants manufacturing vitreous sanitary ware either by the one-fire or the two-fire process, it likewise is in use. It is believed, however, that brief discussion may possibly suggest its use in other branches of the industry.

Advantages

One conspicuous advantage of the gelatine method of glazing ware is the possibility of applying glaze evenly to a green piece. Dipping a complicated piece of ware obviously is not a procedure capable of easy manipulation or of even glaze distribution. By the method under discussion, the glazing of a green piece of ware no matter how intricate the shape, becomes very simple indeed.

A second notable advantage is the toughness of the glaze coat after it has dried. It has literally been glued to the surface of the piece, and as a consequence, rubbing or chipping off during kiln placing is reduced to a minimum.

Another advantage is the ease of maintaining an even coat of glaze on ware which is of such shape that even dipping is attended with some difficulty. Wherever glaze tends to accumulate because of slight flow, a coat or two can be skipped. Also to be remembered is the facility for evenly superimposing a glaze on an engobe, or of using two different glazes should that be desired.

Quality of Gelatine

Before outlining the method, a word on gelatine itself will not be irrelevant. There are five or six general classes of glues and gelatines, and in each class a great number of grades. For this particular purpose a straight hide product seems to be best suited. It cannot be unduly stressed, to provide a strictly high grade product.

The chief requirement of a gelatine for this use is that its jelly strength be great, and hide gelatines are generally considered the strongest and most reliable.

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[1] Presented at Atlantic City Meeting, Feb., 1924 (Whitewares Division).

The form of the gelatine whether flake or ground is quite immaterial. Ground flues (or gelatines) can be used more conveniently, but there appears to be some prejudice against their use due to greater ease of adulteration. Ground glue is to be preferred, if equal in quality to a good flake glue. The higher grade glues when in flake form are usually light in color, and nearly transparent.

The odor of a glue gives some indication of its source or condition. Glue which has a slightly offensive odor is not considered of the highest grade. The nature of the process obviously demands a gelatine of good keeping qualities. This can be determined by allowing a bucket of glaze made up with gelatine to stand in the shop for a number of days, and noting the odor and condition of the gelatine at intervals. Glues with good keeping qualities will stand at least 48 hours in a moderately warm temperature without developing an offensive odor or showing any appearance of decomposition. Some indication of a glue's "keeping" qualities is its reaction to litmus. A slightly acid glue is slightly preferable to one which is neutral or alkaline, for the reason that slight acidity discourages the growth of organisms which promote the decomposition of glue.

By "jelly strength" is meant the firmness or elasticity of the jelly formed by cooling a glue solution of specified strength. Strong glues usually have a high jelly strength. Unfortunately, there is no standard unit for expressing "jelly strength" and consequently there is no way of purchasing it on a "jelly strength" specification which is equally intelligible to all buyers and sellers. Various testing apparatus, based usually on the penetration of some object into a jelly of fixed proportions, are used by different manufacturers, but each laboratory expresses its test results in its own terms and no two agree. Inasmuch as for ceramic purposes the gelatine is never used alone, but always as a medium of suspension, any test which disregards the slip or glaze to be used with the gelatine, is likely to fall short of its purpose.

Contrary to what might naturally be expected, high content of ground material does not necessarily impose the severest test on a gelatine. On the other hand a slip or glaze with a high clay content can generally be relied upon to show first symptoms of weakness in a gelatine. Explanation for this can possibly be found in the acidity of the gelatine, which by promoting coagulation of the clay, accelerates the tendency to settle, and thereby counteracts the influence of the gelatine to uniformly suspend the slip.

Example of Use

The following practical test is offered as a means of trying out gelatines for this use. A slip consisting of 60% sand flint, 20% No. 1 Florida clay, and 20% English china clay is prepared by ball milling for a short time. After setting to a weight of 26 oz. per pint, 10 quarts are measured off into a 3-gallon bucket.

Seven ounces of the gelatine under test are carefully dissolved in one quart of hot water, added to the bucket through a sieve to remove small lumps, and carefully and uniformly stirred into the slip. If the slip is cold, it should be warmed somewhat before the gelatine is added. After standing for five or six hours at a temperature of approximately 35°F, the contents of the bucket should be firmly jellied, with no covering of water. The stiffness of the jelly should suffice to sustain the weight of an average one pint Mason fruit jar, the jar and contents weighing at least one pound. Of several glues tested in this manner, the one producing the firmest jelly would under ordinary circumstances be the best.

For comparative tests of jelly strength, the common method of determining the relative firmness of the jellies is with the outstretched fingers. The finger tips are very sensitive to slight differences. It is to be noted that the quantity of gelatine suggested in the test is a minimum, and that products which can only meet its conditions with an additional ounce or two of gelatine can safely be classed as high grade.

Possible Uses

Definite comment on the ceramic use of gelatine becomes all but impossible owing to the endless variety of circumstances surrounding its use. Different glazes or engobes, as the case may be, will require varying amounts of gelatine; weather conditions vary; green and biscuit ware require different treatment.

One may consider three sources of control in this method of glazing—(1) the specific gravity of the slip or glaze, (2) the proportion of gelatine added to it, and (3) the operation of painting the glaze on the piece. With a slip or glaze at a set weight, experimentation will quickly determine the proper amount of gelatine to be used. It should suffice to produce a firm jelly under all conditions of weather. During warm weather, as a rule, it becomes necessary to increase the amount of gelatine used. It will generally be found to be true that engobes, particularly, if moderately high in clay, will require a larger amount of gelatine than the average glaze. Increasing the proportion of gelatine facilitates application but at the same time diminishes the weight of glaze applied on the piece. In this same connection it is to be noted, that mixtures lean in gelatine slide poorly while being painted, and as a consequence exert considerable "pull" on preceding coats thereby inviting trouble through the formation of blisters. Of importance, also, is that no coat of slip or glaze should be applied until the preceding coat has thoroughly dried. During sudden changes of weather this frequently becomes a source of trouble.

Finally, it is noteworthy that although comparatively simple in all its details, the use of gelatine in glaze application does at times invite a somewhat narrow margin for the maintenance of uniformity. The following will illustrate. Continuous complaint from the glazing department over the lack of uniformity of their glaze led to examinations of the glue being

used and investigations into the care and accuracy exercised in setting the glaze, without leading to an explanation. Finally it was discovered that one of the glaze agitators was leaking slightly, and that consistently there was trouble when preparing glaze from this agitator—this despite careful regulation of the weight of the glaze after it had been drawn off. This glaze incidentally carried no soluble ingredients which might pass off with the leakage and thus slightly derange its composition. Explanation may lie in the possibility of a small loss of colloidal matter in the water which leaked out. At any rate the disturbance was no longer noticed when this particular tank was abandoned.

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[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstract* by coöperative agreement.

Abrasives

Corundum abrasive wheels (Transvaal). F. J. TROMP. *S. Af. Jour. Indus.*, **71,** 27(1924).—Total amt. of Transvaal corundum produced in 1922 was 2,024 T., almost the whole amt. being used for prod. of abrasive wheels. Transvaal corundum is obtained in a very pure form (from 95–98% Al_2O_3), owing to the fact that it occurs in the form of comparatively large crys. of nearly pure alumina, which can be readily separated from the accompanying gravel or enclosing rock. There seems no reason why these valuable deposits should not be the basis of an important industry, provided an export market can be obtained. The industry is discussed under various heads—grits, grades and bonds, glazing and loading, the making of a wheel, speed tests; grinding tests and railway grinding tests, with illustrations and statistics. O. P. R. O.

PATENT

Method of purifying silicon-carbide crystals. CLARENCE J. BROCKBANK 1,488,311, Mar. 25, 1924. The method of purifying silicon carbide crys. or grains that consists in treating the carbide with a solution of a metallic subs. capable of replacing the impurities with its contained metal.

Art

Deposition of metals on glass and ceramics. SAMUEL WEIN. *Met. Indus.*, **23,** 532(1923).—There are 3 methods of depositing metals on non-conducting surfaces. *First method.*—An adhesive (gum, resin, or similar compound) is dissolved, into which are stirred such conducting elements as graphite or metallic powders, or both. This process is the cheapest. The results are quite permanent if done carefully, but with time the deposited metal has a tendency to peel. The process is readily prepd. by dissolving ordinary orange shellac in alcohol to the consistency of thin paint: to this is added graphite (free from oil and grit) or bronze powder or both; this may be applied to the surface by hand or air brush. If the designs are not too fine in detail, paper stencils may be used to advantage. This is placed away to dry (about 1 hr.), proper elec. connections made thereto, and it is ready to be copper-plated. A copper-cyanide soln. is the best for the "strike," and after a while it may be transferred to the ordinary copper-sulphate soln. *Second method.*—A metal or metallic salt is mixed with a flux, and this applied to the surface and then subjected to heat, the object being that the metallic salt is converted into the metal and at the same time fused into the surface proper. This process is by far the best, and at the same time most permanent. It is difficult to remove, once the metal is fused into the surface. In this process "metallized silver" is first made, by adding 1 part nitric acid to 6 parts of water, and one ounce of metallic silver. When the silver is all dissolved it is diluted with several times its bulk of water. Insert a piece of copper; after a time the silver will be pptd. on the copper in the form of white flakes, the silver is then collected, dried and prepd. for use. It is best powdered or ground in a mortar and pestle, or in a paint mill. The formula used by Pottier (first to use metallic silver and a flux) consisted of: silver 75 pts., lead borate 25 pts. These are ground together in a paint mill with a little essence of turpentine and oil of neat's-foot. This compd. is applied to the surface and fired in a kiln. Dimes recommends: silver 1 oz., mercuric oxide 1 dwt. The formulas in the following tables have all been tried and give good results.

Gold may be used instead of silver for deposition; dissolve it in aqua regia, 1 pt. of nitric acid to 3 pts. hydrochloric acid, great care must be taken as these fumes arising are extremely poisonous. When the gold is dissolved, gold chloride in soln. is the result. Metallized gold must be pptd. from this soln.: divide the soln. equally and pour into 4 tumblers, to each add twice its bulk of clear distilled water. Dissolve some ferrous

1	
Silver chloride (fused)	1 oz.
Lead acetate	1 dwt.
Soda ash	1 dwt.
Potassium nitrate	1/4 dwt.
Boracic acid	1/4 dwt.
Borax	1/4 dwt.

2	
Silver chloride (fused)	1 oz.
Lead borate	2 dwt.
Potassium nitrate	2 dwt.
Borax	1 dwt.

3	
Flint glass (powdered)	6 grains
Lead oxide	6 grains
Potassium nitrate	24 grains
Borax	6 grains
Boracic acid	12 grains
Silver chloride	1 oz.

4	
Silver chloride	4 oz.
Boracic acid	4 dwt.
Potassium nitrate	4 dwt.
Flint (powdered)	4 dwt.
Glass (powdered)	4 dwt.
Soda ash	4 dwt.
Lead oxide	4 dwt.
Borax (calcined)	8 dwt.

sulphate in hot water, add the green soln. until a pptn. takes place; the gold will be found on the bottom of the tumbler in the form of a brown powder, when dried and the necessary amt. of flux added, is ready for use. In pouring off the original soln. a slight residue of alloy remains. When the ppt. of gold has been completely extracted, water may be poured off and the brown powder collected and dried, when dried pass through a fine sieve or silk muslin. Due to coarseness of the metal it is difficult to secure even deposits. To overcome this coarseness, prepare a soln. of gold chloride, to this add an excess quantity of potassium hydroxide soln. A ppt. will form; on the addn. of an excess of the alkali the ppt. will immediately redissolve. To this add a soln. of mercurous nitrate until no further ppt. forms. The ppt. is sepd. from the soln. and washed, and then treated with an excess of nitric acid (to dissolve the mercurous salts formed in the ppt.), and then thoroughly washed in running water. By this method the gold is left in an exceedingly fine amorphous condition; it is dried and ready for use. The following is used to great advantage: silver chloride, 1 oz.; gold, 5 dwt.; bismuth nitrate, 40 grains; glass (powdered), 1 dwt.; borax, 18 grains. Platinum can also be used. *Third method.*—The last of the processes is accredited to Marino. This is usually done by applying two or more layers of sodium silicate (water glass). This is best done by dissolving 1 pt. of sodium silicate (sp. gr. 1.27) in 2 pts. water. This is applied as the first coat, and the second coat consists of equal pts. of sodium silicate and water. The surface is brushed over with a soln. of silver chloride 100 pts. dissolved in 140 pts. of a saturated soln. of potassium cyanide to which is added 60 pts. of ammonium fluoride. The silver chloride film is reduced to metallic silver by applying a soln. of 100 pts. hydrazine sulphate dissolved to saturation. To this is added 60 pts. sodium hydroxide or carbonate. The method of procedure is to apply the silver soln., then the reducing soln., and finally submit to friction caused by a rapidly rotating brush. The article thus treated is then ready to be deposited with copper or other metals in the usual manner.

O. P. R. O.

Apparatus for the determination of color in terms of dominant wave-length, purity and brightness. IRWIN G. PRIEST. *J. Opt. Soc. Am.*, **8**, 173–200(1924).—Details of the design of the app. are given together with directions for its use and data on its accuracy. Tests showing that homogeneous and white brightnesses are strictly additive for the wave-lengths and purity values considered are included. D. E. S.

Luster and its measurement. H. SCHULZ. *Textilber.*, **5**, 25–7(1924).—The Goerz "glanzmesser" compares the normal and diffuse reflection of light from a standard

source. Polarization luster-measuring devices require adjustment to the refractive index of the material examd. The device may be used on *artificial silk, paper,* etc. E. R. C. (*C. A.*)

Electrodeposition of antimony. J. C. GHOSH AND A. N. KAPPANA. *J. Phys. Chem.*, **28,** 149–160(1924).—A bath suitable for plating Sb on a large scale is made up by adding Sb_2O_3 to a boiling aq. soln. of 33⅓% tartaric acid to satn., filtering, and then adding 30% HCl. High c. ds. can be employed (50 milliamps. per cm.^{2}); current efficiency runs up to 97%. With oil of bergamot as addn. agent a thin adherent deposit of Sb has been obtained which could be polished to a silvery appearance. G. and K. point out that in a HCl soln. of tartar emetic or Sb tartrate Sb is deposited by the direct discharge of Sb^{+++} ion. A. C. Z. (*C. A.*)

BOOK

HOUSTOUN, R. A.: **Light and Color.** London: Longmans, Green & Co. 179 pp. 7s. 6d. (*C. A.*)

Cement, Lime and Plaster

Exposure tests on colorless waterproofings. Bur. Stand., *Tech. Paper* **248**; *Concrete,* **24** [3], 123(1924).—See p. 191 for this abs. F. T. H.

Rubber lined ball mills in mining and cement industries. ANON. *India Rubber World,* Dec. 1, 1923; *Concrete* (Mill Sec.), **24** [3], 47(1924).—After months of practical test it was demonstrated that the innovation of the rubber lining gives results superior to any of the metal and rock linings previously used in ball mills for grinding very hard ore and gangue rock. The grade of rubber recommended is that used for the tread of automobile tires. While sufficiently hard to resist wear, it has enough resiliency to cause the steel balls or other grinding medium to rebound upon impact in such manner as to avoid disintegration of the liner surface. Also the rebounding action produces a very marked increase in pulverizing efficiency. A method of applying the rubber slabs is covered by U. S. patent No. 1,470,597. F. T. H.

What we may expect to do with aluminate cement. HENRY S. SPACKMAN. *Concrete,* **24** [3], 88–90(1924).—Aluminate cement in France sells at the mills for between 2½ and 3 times the price of Port. cement. All the mills mfg. aluminate cement are oversold. The economies possible in proportions, labor, forms and time offset the increased cost of the cement. F. T. H.

Cementing Qualities of Calcium Aluminates. ANON. Bur. Stand., *Tech. Paper* **197**; *Concrete* (Mill Sec.), **24** [3], 46(1924).—Additional copies of this paper have been printed. It gives the data obtained from test pieces made of eight different cements of this type. The Bureau is doing further exptl. work with aluminate cements. F. T. H.

Recommended specification for quicklime and hydrated lime for the manufacture of silica brick. ANON. Bur. Stand., *Circ.* **153.**—A brief description of the way in which lime is used in the manuf. of silica brick is followed by a general statement as to the quality of lime required. The standard of quality is set at 92%, based on the nonvolatile matter, with maximum limits of 5 and 10% carbon dioxide, depending upon whether the sample is taken at point of shipment or of destination. Complete directions for sampling and testing are included. H. F. S.

Rapid slaking of lime. J. E. DUCHEZ. *Rev. Mat. Constr. Trav. Pub.,* **164,** 80–2; **165,** 104–7; **166,** 127–30(1923).—In slaking burned lime contg. silica and alumina just sufficient water is added to slake the lime but not enough to hydrate any silicates or aluminates. The quantity of water to be used can be calcd. from the empirical formula, per cent water by wt. $= c - 1.7(a + b)/3$, in which the chem. compn. in wt. per cent is a SiO_2, b Al_2O_3 and Fe_2O_3, c CaO and MgO. The formula is derived from the follow-

ing considerations. The compds. formed from SiO_2, Al_2O_3 and CaO in making hydraulic cements are mainly, $SiO_2.2CaO$, $SiO_2.3CaO$, $Al_2O_3.3CaO$ and free CaO. In burning lime with mol. compn. x SiO_2, y Al_2O_3, n CaO, granting that the above compds. are formed, the max. and minimum free lime left for hydration will be: (*a*) $x(SiO_2.2CaO) + y(Al_2O_3.3CaO) + [n-(2x + 3y)]CaO$; (*b*) $x(SiO_2.3CaO) + y(Al_2O_3.3CaO) + [n-3(x + y)]CaO$. As the free lime only should be hydrated, the limits for the water content are: $[n-(2x + 3y)]H_2O$ and $[n-3(x + y)]H_2O$. Converting the per cent chem. compn. of the lime into mol. ratios gives, $0.93a$ SiO_2, $0.55b$ Al_2O_3, $1c$ CaO. Substituting these values, the limits in wt. per cent are $^1/_2[c-(1.80a + 1.65b)]$ and $^1/_3c-[(2.80a + 1.65b)]$; the fraction $^1/_3$ being the ratio of water to lime used for slaking theoretically pure lime. Equalizing the factors in the max. limit gives the empirical formula. The calcd. values agree with the quantities used in practice:

Lime from— wt. per cent compn.	Tarn.	Aude.	Cantal.	Basses-Alpe
SiO_2	4.5	0.75	16.32	25.21
Al_2O_3 and Fe_2O_3	3.1	0.32	4.00	1.32
CaO and MgO	91.94	97.70	77.58	72.00
Water of hydration. wt. per cent				
Calcd. from formula	26.04	31.29	14.34	8.96
Used in practice	25	32	15	10

Lime crushers, hydration systems and storage bins are described with special reference to installations made by the author. L. N.

Calcium chloride and concrete. ANON. *Nature*, **113,** 441(1923).—Three valuable processes for improving concrete have resulted from recent scientific study; hardening after setting with a dilute soln. of silicate of soda; the addition of mechanically slacked lime to the cement; and the use of calcium chloride for "curing" and also for mixing cement. With regard to the curing of cement, concrete requires to set in a continually moist condition in order to give the best results. For this reason, therefore, curing consists in keeping it wet either by covering with water or spreading over it damp soil or earth which is moistened continually. This is an extremely costly, laborious, and tedious job in case of a long stretch of road and is often not particularly efficient. The calcium chloride treatment consists in spreading the powdered material over the road as soon as it has set at the rate of 2–$2^1/_2$ lb. per sq. yd.; its deliquescent properties keep the surface continually moist without any trouble, the net saving in cost being very considerable. Calcium chloride is beginning to find a use for mixing with the cement, in the propn. of about 3%, which results in a much quicker hardening of the concrete for given strength and a final increase in the compressive strength, although the matter in this respect is somewhat complicated because, for some unknown reason, different cements do not react to some extent. O. P. R. O.

Cement industry—Portland and Kandos (New South Wales). R. H. CAMBADGE. *Chem. Eng. and Min. Rev.* (Melbourne), **16,** 153(1923).—The cement industry may be relied upon for 1924, as the value for 1923 was so high action has been taken toward establishment of additional cement works. O. P. R. O.

Exposure tests on colorless waterproofing mats. Bur. Stand., *Tech. Paper* **248.** D. W. KESSLER.—Tests to det. the rel. effectiveness and durability of several colorless waterproofing mats. H. F. S.

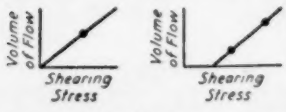
PATENT

Dampening the kiln gases before the electric precipitation of the flue dust. DALEN PORTLAND CEMENTFABRIK. Norw. 37,660, Aug. 20, 1923. The gases pass through a chamber the walls of which are sprinkled with the necessary amts. of water.

C. H. A. S. (*C. A.*)

Glass

New method of cutting glass. ANON. *The Glass Worker*, **43** [26], 15(1924).—From the *Scientific Amer.* Large sheets of glass are cut in a new machine which has two cutters for scoring the glass on both sides at identical lines. The glass comes apart with no ragged edges. No allowance for gaging is necessary. R. J. M.



On the physical properties of glass. F. ECKERT. *Jahrbuch der Radioaktivitat und Elektronik*, 20 Band Jahrg., 1923; Heft 2/3, pp. 94–275; Leipzig Verlagvon S. Hirzel, 1924.—This vol. contains nearly 200 pp. describing and discussing the phys. properties of glass. Detailed subjects, General Glass Lit.; Optical Glasses and their Optical Constants; Dispersion of Optical Glass; Absorption of Optical Glass; Absorption of Colored Glass; Effect of Absorbed Energy; Relation of Refractive Index to Composition, Pressure and Temp.; Reflection and Elliptical Polarization; Electro and Magneto Optics; Electrical and Magnetic Properties; Density and Thermal Expansion; Thermal and Molecular Properties; Elastic Properties; Behavior of Glass at High Temp. W. M. C.

The influence of light and temperature on the change of color in the production of colorless glass in tank furnaces with special reference to the use of selenium. W. E. S. TURNER and A. COUSEN. *Pottery Gaz.*, **49**, 445–49(1924).—Previous exptl. (cf. *Ceram. Abs.*, **2** [5], 94; **3** [3], 96) work had been done by the authors with regard to the effect of color of the glass of the various substances employed in batches for the production of a selenium decolorized glass. A standard batch of the compn. 100 pts. sand, 37 soda ash, and 20 lime spar was used as a basis, with variations by replacing a small propn. of the soda ash by its equiv. either of salt cake, sodium nitrate or of borax. Meltings were made in crucibles at temp. about 1370–1380°C. It was found, that by using an amt. of selenium such as normally employed in decolorizing, *viz.*, $^1/_2$ oz. per 1000 lb. of sand and keeping Fe_2O_3 content of the glass from 0.4% to 0.6% the glasses obtained in 3 hrs. melting were either decolorized or pale yellow with no certainty of color. Additions of arsenious oxide to the batch, and 3 hrs. melts under above conditions were made, which resulted in the production of glasses in which no yellow color was present. Where selenium was used in large excess, arsenious oxide contg. glasses gave a faint pink coloration. Sodium nitrate when substituted for some of the soda ash, gave glasses much deeper in color than those obtained without its use. There was no difference in appearance between borax and a simple soda lime glass. A period of $8^1/_2$ hrs. melting was then employed with following results. (1) Simple soda lime glasses, which, at the end of 3 hrs. were decolorized, or pale yellow, after $8^1/_2$ hrs. were deep yellowish brown. (2) Glasses in which a small amt. of salt cake displaced some of the soda ash, and which were decolorized after 3 hrs. or at most faintly yellow with prolonged heating became definitely green in color, the color being that due to iron oxide. (3) Arsenious oxide glasses, decolorized or practically so, after 3 hrs. were decolorized even after heating for $8^1/_2$ hrs. (4) Sodium nitrate batches became very deep brown in color when heated for the longer period. (5) Again, sodium selenite melts, which were somewhat deeper in color than those in which selenium itself was employed at the end of 3 hrs. differed little from these when long period meltings were tried. The amt. of selenium remaining in the glass was detd. and the following relationships found: (1) In all cases when salt cake was employed the amt. of selenium remaining was very small, so small as to be impossible of estn. by the method used. (2) With arsenious oxide glasses, the amt. of selenium retained was of the same order as with simple soda ash glasses. (3) With sodium nitrate batches the amt. of selenium retained was of a much larger order, and it seemed obvious that the amt. of the substance remaining in the glass was dependent upon the rate of melting of the batch, for it was clear that sodium nitrate batches melt more readily than

equiv. batches in which soda ash only is employed. It appeared in all cases so far examd. the element when in the glass did not become oxidized to selenite, but remained as selenium, its color being developed slowly as the result of continued heating. It therefore seems from the results obtained that the only stabilizing substance tried was the arsenious oxide, the salt cake tending to eliminate the selenium from the glass. Glasses were exposed to sunlight for a period of a year and two distinct results were obtained depending upon initial appearance, *i. e.*, whether deeply colored or practically free from color. The deeply colored glasses were distinctly bleached by the exposure, while the decolorized or faintly colored glasses became slightly yellow. Pink glasses obtained by use of selenium and arsenious oxide, also with selenium and sodium nitrate upon annealing became distinctly paler after 8 hrs. at 525°C, after 3 hrs. at 550°C and even at 1 hr. at 575°C. J. W. H.

The art of table and domestic glass making. F. A. PERRY. *Pottery Gaz.*, **49**, 267–73(1924).—An address bearing upon the processes in the making of glass for domestic use. J. W. H.

Simplified practice recommendation No. 10—milk and cream bottles and bottle caps. ANON. Bureau of Standards.—Representatives of the International Milk Dealers Assn., The Glass Container Assn., the Cap Mfrs. Credit Assn., and the National Assn. of Bottle Mfrs. met in a general conference at the Department of Commerce on April 26, 1923, to det. upon recognized sizes of milk bottles and milk bottle openings. The conference unanimously recommended three sizes of milk bottles for quarts, pints, and half-pints, respectively, with one size opening for the entire group. Before this constructive step milk bottles were manufd. in 12 sizes for quarts, 13 sizes for pints, 14 sizes for half-pints, 10 sizes for quarter-pints, and approx. 10 sizes of caps were required to fit this varied assortment. H. F. S.

Operating glass tanks—heat requirements of the batch-efficiency. BJARNE SCHIELDROP. *Fuels and Furnaces*, **1** [1], 43(1924).—The third of a series of articles on heat balances of glass tanks, dealing with ht. requirements and efficiencies of the batch. After batch has been introduced in the tanks, the sequence of events is assumed to be as follows: 1. Raw mats. are htd. to fur. temp. 2. Fluxes not entering into the glass, are dissociated. 3. Silicates are formed by the sand and the parts of the fluxes remaining in the bath. 4. Glass resulting from item 3 is fused. 5. Gases escaping from the batch are cooled to stack temp. 6. Glass is cooled to working temp. The amt. of ht. reqd. to melt the batch varies with the following factors: 1. Compn. of the batch mixt. 2. Temp. at which glass is withdrawn from tanks. 3. Stack temp. Using these items, a table is given showing eff. of fur. with def. wts. of raw mats. and temps. Items 5 and 6 are found from tables showing amts. of ht. given off in cooling 1 lb. of glass from 2600°F to temps. varying from 1500°F to 2400°F (working temp.) and cooling 1 lb. of gases given off from the mat., from 2600°F to temps. varying from 500°F to 1200°F (stack temp). The eff. figured is on the basis of fuel consumption given in a preceding article (Dec. 1923). The author points out that reductions in stack- and glass-withdrawal temps. result in increased eff. on account of decreased fuel consumption that overbalances the corresponding decrease in items 5 and 6. Before batch calcns. can give constructive information as an aid to design and opern., they must be available over a period covering both good and bad "runs." Well-designed and operated window glass tanks should show eff. of around 10 per cent. If below 6%, a strenuous effort should be made to det. cause. Flint or bottle glass tanks may reach 20% eff., but is commonly around 10 or 12%. A mere statement of fuel consumed per lb. of raw mat. is no indication of eff. R. D. L.

Canadian Glass Co. (new process). A. A. ICENHORN. *Indus. Canada*, **24**, 84 (1924).—The Canadian Glass Co. is to start operations shortly at Amherstburg, Ont.,

mfg. plate glass by a newly invented process, the work of A. A. I. It involves a great saving in production costs over previous methods. By it the glass will be drawn by a special machine directly from the melted batch. When drawn to the proper dimension, the plate is automatically passed to a leer, where it is annealed, and it is then ready for shipment. The rate of production is one sheet every 25 min. No grinding or polishing is necessary. The process has been tested experimentally and the company is now building a machine of commercial size at a cost of about $250,000. The factory is situated near an almost unlimited supply of silica sand. O. P. R. O.

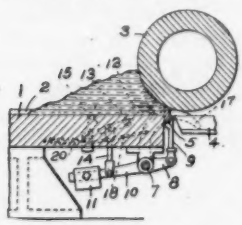
The art of sealing base metals through glass. WM. G. HOUSEKEEPER. *Jour. Am. Inst. Elec. Eng.*, **42,** 954–60(1923).—Four distinct methods of sealing metals to and through glass are described: (1) the flattened wire seal for small electrical conductors; (2) the ribbon seal for special purposes; (3) the disk seal for commercial manufacture of seals for carrying currents of the order of 100 amp.; (4) the tube seal, in which metal and glass tubing are joined together. The method consists in providing a large surface of contact between the glass and the metal, and in so proportioning the cross section and contour of the metal that the stresses resulting from the difference in coefficients of expansion are less than the ultimate strength of the joint between glass and metal. Since the metal (copper) is under tension, due to its greater contraction on cooling, it follows that heating of the conductor will relieve the stress, and in this way it is possible to pass sudden currents as great as 1200 amp. through a disk seal. A. F. G.

Unsplinterable glass. ANON. *Indus. Aust. and Min. Standard*, **7,** 224(1924).—A description of the processes and manuf. of the commodity known as "Triplex Safety Glass" used extensively for the wind shields of automobiles. While it is tougher than ordinary glass, it is not unbreakable, but is unsplinterable, which is its chief virtue. As a result of impact tests it was proven that while the glass was covered with innumerable cracks, no single piece was detached. France was the original home of the product, but the British product is now superior. A description of the process of mfg. is given by mentally following a piece of glass through the works. The special features of this process are the specially prepared adhesive with which the two sheets of glass are coated and the uniting of the glass sheets with a sheet of celluloid by means of hydraulic pressure. Great care and skill is required in the manuf. and expensive mats. are the only ones practical, but the many years of experiment have resulted in a product, the advantages of which are obvious. O. P. R. O.

Annealing of glass. H. V. MALLISON. *Science Progress*, **18,** 473–6(1924).—Mathematical evidence is offered that glass may be annealed in 2 ways. It may be annealed quickly at a relatively high temp. and cooled slowly; or it may be annealed slowly at a relatively low temp. and cooled quickly. J. S. H. (*C. A.*)

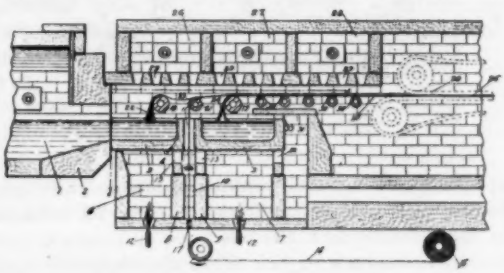
Unbreakable and malleable glass. E. BERGER. *Naturwissenschaften*, **12,** 79–83 (1924).—A review dealing with the physics involved and with past attempts to produce glass highly resistant to mech. and thermal fracture. C. C. D. (*C. A.*)

PATENTS



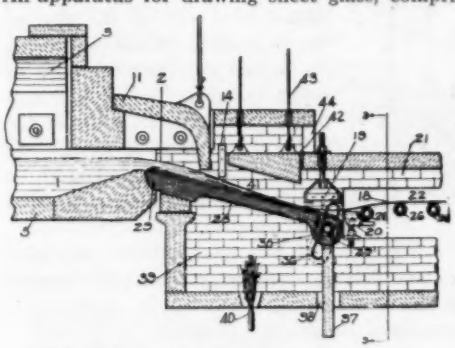
Casting table. ALBERT E. EVANS. 1,488,911, April 1, 1924. In combination with a glass casting table, a stop member mounted for vertical movement up and down across the edge surface of the table at one end thereof, and adapted in one position to be withdrawn below the upper surface of the table, and in another position to extend above such upper surface and form a stop for the molten glass cast upon the table, a roll mounted for movement from a position directly above the stop member to the other end of the table and means for moving the member up and down.

Composition for producing glass. ALEXANDER L. DUVAL D'ADRIAN. 1,489,026, April 1, 1924. A composition for producing glass, comprising the constituents of the usual glass bath, and the natural double silicate of sodium and calcium known as pectolite.

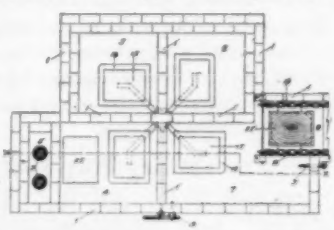


Method and apparatus for drawing wire glass. JOSEPH P. CROWLEY. 1,489,822, April 8, 1924. An apparatus for making wire-glass comprising, a receptacle containing molten glass, a pair of spaced parallel cylindrical cooled rollers mounted closely above the surface of the molten glass, means for feeding up a sheet of wire mesh at a point between the rollers, and a third roller intermediate the other two over which this wire is bent, a drawing mechanism for drawing up a mass of molten glass over each of the first rollers, and drawing a sheet horizontally from these masses, the sheet from one roller passing first over the intermediate roller and uniting with the wire, and then over the second roller and uniting with the glass drawn from the second mass of molten glass, to form a sheet of glass with the wire embedded therein, and means for directing heat against both faces of the sheet to insure the union of the several constituent parts.

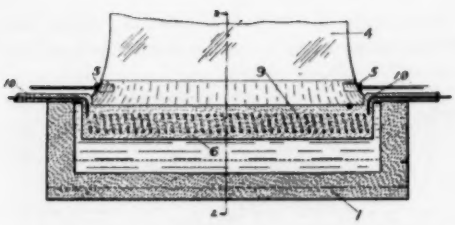
Drawing continuous sheet glass. JOSEPH P. CROWLEY. 1,489,823, April 8, 1924. An apparatus for drawing sheet glass, comprising a tank containing molten glass, a graphite drawing slab pivoted to the tank outlet so that the molten glass flows out onto the slab, a cooled supporting shaft for the free end of the slab, means for adjusting the shaft vertically to vary the inclination of the slab, a heating chamber beneath the slab, the front wall of the chamber being vertically adjustable with the slab, means for cooling the glass while on the slab, and means for stretching the glass into sheet form while on the slab.



Rotating glass-molding device. FRANK AUCREMANNE. 1,489,729, April 8, 1924. In combination with a four-chamber, glass heating furnace, of the character described, a rotating, glass-molding device, having a centrally located, stationary, base hub; a vertical journal guide, upon the upper surface of said hub; a rotating hub member, adapted to pivotally engage the guide journal of the stationary hub, and adapted to rest and rotate upon the upper surface of the stationary hub, by means of ball bearings; a plurality of carrying arms, rigidly attached to the rotating hub, and means for rotating said hub and arms, within the heating chambers, substantially as described.

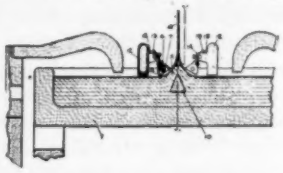


Drawing continuous sheet glass. JAMES WHITTEMORE. U. S. 1,489,875, April 8, 1924. In an apparatus for drawing sheet glass from a mass of molten glass, a

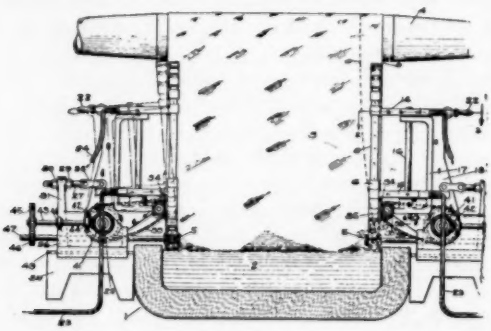


wedge-shaped member of refractory material, located within the molten mass with its edge tapering toward the line of generation of the sheet, and an electric heater enclosed within the refractory member.

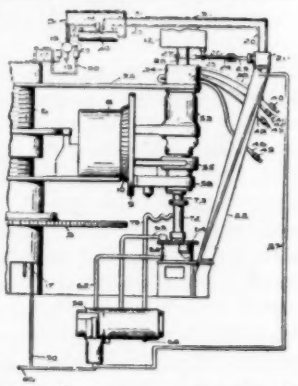
Drawing sheet glass. JAMES WHITTEMORE. U. S. 1,489,876, April 8, 1924. In a sheet glass drawing apparatus, a receptacle containing molten glass, means for drawing a sheet therefrom, a cooling bar submerged in the glass beneath the meniscus, and electric heaters extending across each face of the sheet near the base of the meniscus.



Drawing continuous sheet glass. CLIFFORD A. ROWLEY. U. S. 1,489,852, April 8, 1924. In combination with a source of molten glass, and means for drawing a sheet of glass therefrom, a pair of guide loops, a series of grippers freely slidable on each loop, a driven sprocket for feeding the grippers around the lower arc of each loop into engagement with the sheet, an idler sprocket for enforcing uniform movement of the grippers around the upper arc of each loop, a frame yieldingly holding the loops and grippers, one against each side of an edge of the glass sheet, means for cooling the loops, a supporting base to which the frame is pivoted, and means for angularly adjusting the frame about its pivot to vary the inclination of the guide loops with respect to the line of travel of the glass sheet.



Molten-glass charge supply. FRANK O'NEILL. U. S. 1,490,182, April 15, 1924. Means providing a downwardly continuously flowing laterally peripherally exposed stream of molten glass, a normally open shear, means for operating the shear for severing the stream of glass into slugs, a guide in the line of the stream, therebelow and approximating in cross-sectional area the cross-sectional area of the stream, for receiving the slugs, an annular series of molds successively movable into registering position with the guide, suction means coacting through a guide registering mold, and control means for the shear and suction means for at once accelerating the slug as it is severed for travel through the guide into the mold therebelow.

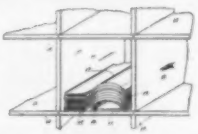


Heavy Clay Products

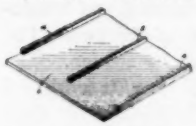
Making sewer pipe the modern way. STAFF ARTICLE. *Brick and Clay Record*, **64**, 492–96(1924)—. Description of new plant of Cannelton (Ind.) Sewer Pipe Co. Numerous photos of equipment accompany the article. J. W. H.

PATENTS

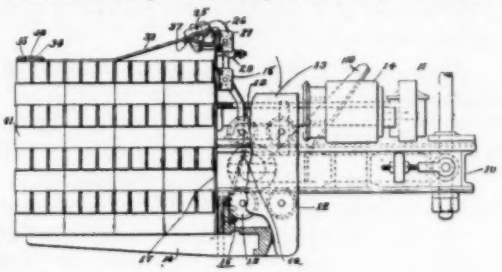
Method of and means for burning tiles. ARTHUR W. BROWN. 1,489,694, April 8, 1924. A method of burning tiles having arch portions, consisting of arranging the tiles in loose bundle-like portions in a kiln and supporting the arch portions thereof during baking of the tiles.



Brick pallet. JAMES H. MCFEELY. U. S. 1,490,119, April 15, 1924. A rolled metal pallet for use in the manufacture of bricks having a longitudinal stiffening rib along each side thereof and a longitudinal stiffening rib along the center thereof, said ribs terminating short of the pallet ends so as to provide supporting slideways.



Clamping device for brick-handling machines. GRAFTON E. LUCE. U. S. 1,490,898, April 15, 1924. In a clamping device for brick handling machines, the combination of a stationary plate, a clamp pivotally mounted thereon and extending forwardly thereof, a movable frame adapted to carry a load or pile of bricks and located beneath the clamps, and means on said frame for operating the clamping device to clamp a load or pile of bricks on the movable frame.



Refractories

The story of refractories. ANON. *Science*, **59** [1525], 275 (1924).—A motion picture film made by the Bureau of Mines is loaned free to technical societies, commercial organizations, colleges, schools and churches. Applications should be addressed to Department of the Interior, Bureau of Mines, Pittsburgh, Pa. C. J. H.

Refractories. G. M. GILL. *Colliery Guardian*, **123,** 91(1922).—The variation in size and quality of firebricks, blocks and retorts is one of the most unsatisfactory features users of refractories have to meet. To solve the difficult problems arising from varying length, width, and thickness of fire bricks, the author suggests that dimensions of retorts should be, within practical limits, the same from end to end, internally and externally; the internal dimensions affect the discharging operations, the external dimensions affect the building of the settings, much cutting of bricks and blocks being necessary where the retort is of bad shape. What appears to the author as necessary in the conduct of firebrick works is the institution of methods providing for: (1) The continuous sampling and analyses of mixts. in use, both chem. and phys. (2) The use of heat recorders in kilns. (3) Definite limiting standards for size and shape. (4) Guaranteed working to specif. The control proposed would doubtless effect the production of a higher and a more consistent quality of brick. Control would further diminish rejected bricks, save fuel costs in kilns, increase capacity of plant and effect improvements which would entail from increased knowledge of the process.

O. P. R. O.

Silica brick works of the Consett Iron Co. ANON. *Colliery Guardian*, **126,** 1163 (1923).—A detailed description of this plant for manuf. of silica bricks and shapes for the construction of the new installation of Willputte coke ovens now being erected at Consett. The raw material—ganister—is mainly composed of silica in the form of quartz with a density of 2.650. The "Consett" silica shapes contain about 30 per cent tridymite and never more than a trace of unconverted quartz; hence this practically com-

plete conversion guarantees absence of either permanent or after expansion. The article has illustrations of the works and details of construction. O. P. R. O.

Silica bricks in coke oven construction. J. ENZENAUER. *Colliery Guardian*, **121,** 565(1921).—Two batteries of ovens built, the one in 1915 of silica bricks (SiO_2 95%, CaO 2%) and the other one year later of ordinary coke oven siliceous bricks (SiO_2 80%, Al_2O_3 16%), are described by E. in Glückauf. The higher thermal conductivity of the silica brick was recorded in a shorter coking period, 24 hrs. as against 29 hrs. in the latter battery. In spite of the initially unpromising texture and brittleness of the silica brick walls, they are now in the better condition of the two. The siliceous bricks are more extensively corroded by salt and more worn by erosion. The walls of silica brick are less susceptible to fusion or deformation due to unskilled attention. The yield of by-products may possibly be adversely influenced in the silica brick construction, but this does not outweigh the advantages of increased output of good coke and of gas. The fact that higher temp. may be maintained in flues of silica brick without damage to the walls may be a temptation to shorten the coking period at the expense of by-products, but the rise in heat consumption finally renders such practice uneconomical. O. P. R. O.

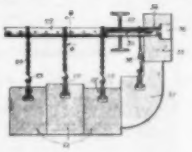
Graphite, 1919–1921. *Imp. Min. Res. Bureau*, 16 pp.(1923).—The world's production of graphite, imports and exports for United Kingdom, Canada, Ceylon, India, Australia, France, Germany, Italy, Sweden, Madagascar, U. S., and Japan, are given in this statistical report, with prices and bibliography. O. P. R. O.

The casting process for glass refractories in German glass tank process. K. ENDELL. *Pottery Gaz.*, **48,** 1964–67(1923).—The principal advantages of the casting process compared with older methods of making pots by hand are (1) a very homogeneous mixt. of the raw clay and grog is obtained, which results in a close texture after firing; (2) unskilled labor is employed in place of highly rated men. The process is not only used for the casting of pots but also for producing large tank blocks and slabs. The difficulty arising in a wider adoption of the process lies in the discovery of suitable casting clays. The suitability of a clay for casting depends upon the possibility of obtaining with the clay and grog mixt. a pouring consistency suitable for casting by the addn. of about 0.25% alkali and 18 to 20% water calcd. on dry wt. of the mix. Many clays which are suitable for making glass pots require too much water to produce a casting slip, for example, Grossalmerode pot clay and Belgian crucible clay from Ardenne region. The difficulties with these clays are due principally to sol. salts such as sulphates. Work is now in progress on freeing clays of sol. salts by electrolysis. In certain clays fluidity can be improved by a small addition of sulphate lye. No difference in refractoriness could be detected in Seger cones between cast and hand made pots, and no perceptible difference was noted between the 2 methods when tested for ability to withstand load at elevated temp. Introduction of finely divided quartz as such or in the form of raw china clay into fire clay mixts. increases the rigidity of the fire clay at high temp. Cast pots are approx. 25% denser than hand made pots, which gives preference to cast pots in melting special glasses such as heavy barium glass which attack fire clay readily. The porosity of cast pots gave values between 19 and 22% whereas hand made pots of the same clay approximated between 24 and 26%. Success of the casting process depends upon careful and trained supervision, proper selection and preliminary treatment of clay. J. W. H.

Intrinsic values of refractory coatings. H. M. CHRISTMAN. *Fuels and Fur.*, **2** [1], 71(1924).—A summation of the destructive forces attacking the refractory and a means of prolonging its life. Coating refractory linings with efficient refrac. cements is suggested to increase furnace efficiencies by preventing corrosive and erosive actions of furnace gases, flames and sand and dust particles, rotting and spalling. R. D. L.

PATENT

Arch construction for furnaces. FRANK B. BIGELOW. 1,488,660, April 1, 1924. In a fur. arch structure, the combination of an arch-plate, an arch-plate brick mounted thereon, a brick arch having a border brick at least in part over said arch-plate brick, and means supporting said border brick from above and capable of permitting variation in the contactual relation of such arch-plate and border bricks.



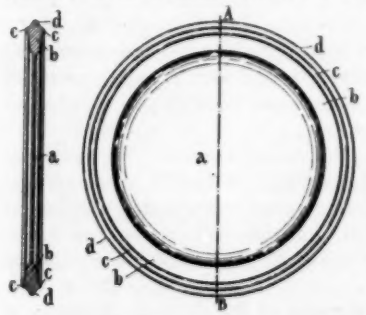
Whitewares

Note on the so-called kaolin of Djebel Debar. A. A. GRANGER AND P. BREMOND. *Trans. Ceram. Soc.*, **22,** 283–285.—In view of the whiteness of the mat., it might be considered valuable in china and earthenware making, but its want of plasticity is a serious drawback in the molding, profiling and casting processes. It should be added to the body in limited quantities only, since it would be incorrect to substitute this halloysitic mineral for china clay. The most serious inconvenience is the necessity to crush the clay with water in a stone or roller mill, the disaggregation with water in the blunger being absolutely ineffective. H. F. S.

The production of earthenware from the biscuit state, including the various stages of decorating. EDMUND SHENTON. *Pottery Gaz.*, **48,** 1947–60(1923).—Abstract of lecture dealing with various kinds of underglaze decoration of English earthenware, *viz.*, sponged ware, band and line printing, the function of hardening kilns. Other topics discussed are underglaze litho, preparation of glaze, dipping, glost placing, glost fire, sorting, liquid gild on glaze printing, hand painting, lithographing on glaze band and line in colors and in gold, ground laying, aerographing, enamel kiln fire and placing. J. W. H.

A century of Straffordshire pottery. WALTON STANLEY. *Pottery Gaz.*, **48,** 1960–63(1923).—An address. J. W. H.

Earthenware biscuit firing. A. G. RICHARDSON. *Pottery Gaz.*, **49,** 273–75(1924).—In the early stages of firing, up to approx. 450°C, an ordinary earthenware body loses 2% of its weight, this loss in weight is almost entirely due to the evaporation of combined water. At 500°C the loss in weight is 3%; at 550°C, it is 5%; at 600°C, it is 6% (the loss now being due to the C as well as moisture) and at 900°C the loss is 7%. No perceptible change in dimensions of the ware occurs until about 1000°C, when contraction takes place rapidly, the contraction at this temp. is approx. $1^1/_2$%; at 1050°C 2%; at 1100°C 4%; and at 1200°C as much as 6%. In ordinary 18 ft. biscuit kiln there is about 10 cwt. of H_2O which must be driven from the ware, and 5 cwt. from green saggers. J. W. H.

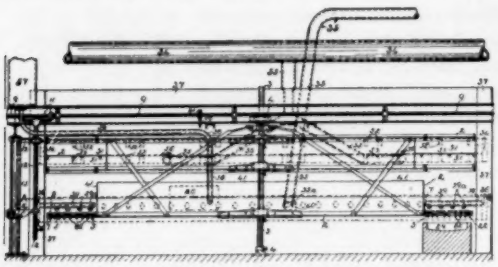


High-voltage (porcelain) insulation. J. L. R. HAYDEN AND C. P. STEINMETZ. *J. Am. Inst. Elec. Eng.*, **43,** 36–43(1924). P. D. V. M. (*C. A.*)

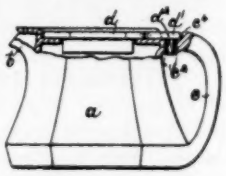
PATENTS

Plate or saucer. EDMUND WILLIAM ABRAM. U. S. 1,488,462, April 1, 1924. A reversible plate or saucer in the form of a one-piece unitary disc dished on both sides thereby to form on each side the food-receiving cavity, said disc having on each side an up-standing bead adjacent its periphery which forms the rim of each dish cavity, said disc extending radially beyond said beads and the extended portion having a progressively decreasing thickness and terminating in a peripheral bead which is located in the plane of the common bottom of the two dishes.

Method of and means for manufacturing teacups, breakfast cups, and other vessels or articles of pottery. ELIJAH BROOKES. U. S. 1,488,973, April 1, 1924. In a casting machine, a frame mounted to revolve on a vertical axis, horizontal mold carriers pivoted in the frame with their pivots arranged radially of its axis, molds arranged in the said mold carriers, and means for tilting the mold carriers on their pivots to discharge surplus material from the molds..



Teapot, coffeepot, jug, and like pouring vessel. JAMES WEBSTER. U. S. 1,489,872, April 8, 1924. In a pouring vessel, a body portion provided with a handle and having a hole at the upper part of the handle and a projection of the handle adjacent to the hole, and a lid disconnected from the body portion and provided with a projection which is slidable vertically in the said hole, said lid having its top portion adjacent to the handle arranged substantially flush with the said projection on the handle.



Equipment and Apparatus

Reduction of blast furnace lining disintegration. H. E. TOWNSEND. *Iron Trade Review*, **74** [3], 232–4(1924).—Linings manufd. in accordance with specif. given by J. W. Gocher showed great reduction in amt. of disintegration. Ferric oxide content was more than 50% lower than usual. Furnace temp. and high CO content in fur. gas were favorable to disintegration. Presence of from 0.10 to 0.15% Zn, in ore mix. substantiates statement by Nesbitt and Bell that "apparently zinc does not cause failure by disintegration." Author states, "ferric oxide content of blast fur. brick must be 50% lower than that of brick usually furnished." T. D. H.

New cupola furnace. E. SCHURMANN. *Iron Trade Review*, **74** [5] (1924).—Two photographs and one complete drawing are given. Blast is preheated and passes transversly across cupola melting zone. Arrangement of refrac. brick checkerwork conserves heat. Pressure and exhaust fans are used and a substantial saving in coke consumption is claimed. T. D. H.

Graphite-clay crucibles for steel. R. T. STULL AND G. A. BOLE. *Iron Trade Rev.*, **74** [7], 487(1924).—Crucibles made from Alabama, Canadian, Ceylon, Madagascar, Montana, New York and Texas graphites bonded with various clays and used on commercial scale for steel and brass melting showed some domestic clays superior to Klingenberg clay. Texas, Alabama and Ceylon graphites, in addition to giving longer life to crucibles, carbonize steel less. T. D. H.

Equalizer app. for transverse tests of bricks. H. L. WHITTEMORE. Bur. Stands., *Tech. Paper*, **251.**—The A. S. T. M. has described the app. to be used for making transverse tests of bldg. bricks. As this app. is made up of many loose parts, considerable time is required to prep. the specimen for test. A new equalizer app. has been designed, built and tested, which gives practically the same values for the modulus of rupture as the A.S.T.M. app. H. F. S.

Application of the interferometer to measurements of the thermal dilatation of ceram. mats. GEORGE E. MERRITT. Bur. of Stands., *Sci. Paper*, **485.**—In this paper an interference method and app. for measg. the thermal expansion of ceram. mats. are described. The samples in the form of small pins, 0.5 to 10.0 mm. in length,

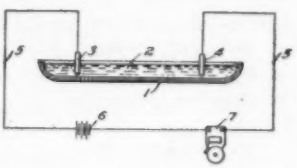
are placed between two fused quartz interferometer plates and heated in an elec. fur. The elongation of the samples is detd. from the numbers of interference fringes that pass reference marks on the interferometer plate while the sample is being heated. A change in length of the sample of 0.025 μ or one-millionth of an in. can be easily detected. H. F. S.

Simple rules for designing resistors. DUDLEY E. FOSTER. *Fuels and Furnaces*, **1** [7], 529(1923).—Design of special resistor furn. is given for any desired temp. up to 1800°F, using nickel-chromium and nickel-chromium-iron alloy wire. Tables for calc. of radn. and convn. losses and proper size and length of wire for definite power input, are given. Example is shown for calcg. necessary power input for a furnace 4 x 4 x 4 in., inside dimensions, with 4 in. insulation. The article provides simple and definite rules for designing small resistor furnaces. R. D. L.

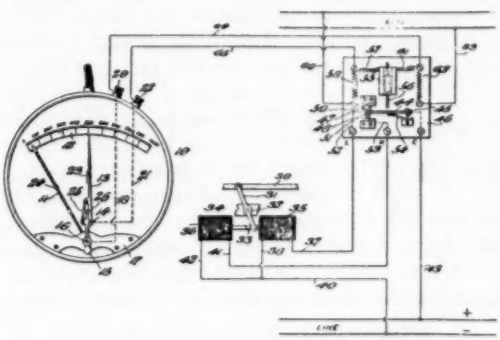
Boilers and engines: How to run them efficiently. J. PHILLIPS. *Trans. Ceram. Soc.* (Eng.), **22**, 286–292. H. F. S.

PATENTS

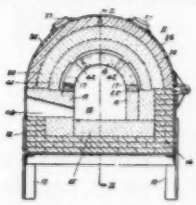
Furnace indicator. CHARLES W. HILL. U. S. 1,489,247, April 8, 1924. A furnace indicator comprising resistance material capable of changing its resistance under reducing conditions.



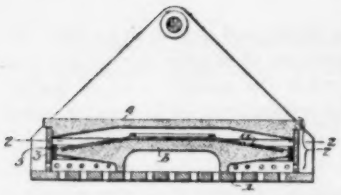
Control thermometer. CHRISTIAN WILHJELM. U. S. 1,489,911, April 8, 1924. In a control system, the combination of a mechanism for controlling the source of heat to a heating zone, a measuring instrument provided with a pointer for indicating the temp. of said zone, a normally energized relay coil, means including a contact arm to coöperate with said pointer when the temp. reaches a predetermined limit to short circuit said relay coil, and means controlled by said relay for operating said mechanism.



Electric furnace. ORA A. COLBY. U. S. 1,490,207, April 15, 1924. In an elec. resistance fur., in combination, a plurality of refrac. walls enclosing a fur. chamber, heating element located in said chamber and comprising a plurality of curved and parallel-extending refractory members of substantially semicircular acurate extent and having their lower ends supported by certain of said walls, refrac. means located at one end of said curved members for elec. connecting them in series-circuit relation, refrac. means located at the other ends of said curved members for maintaining them in substantially parallel relation, terminal electrodes having one end extending through one of said walls and operatively engaging said heating element, and resilient means for maintaining said electrodes in close operative engagement with said heating element.



Process and apparatus for drying pottery. JOSEPH L. BUCKLEY. U. S. 1,490,765, April 15, 1924. In an app. for drying clay bodies, the combination with a tray, a mold

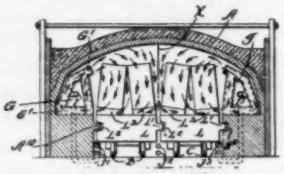


positioned on said tray adapted to support an article to be treated, a metallic ring embracing the periphery of said mold, said ring having one end closed by said tray, and a cover plate of absorbent material for closing the other end thereof, whereby moisture formed on said article, when the same is heated, may be removed.

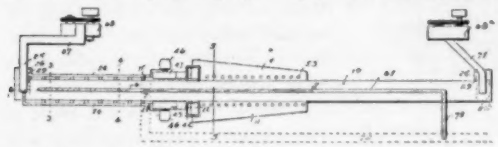
Kilns, Furnaces, Fuels and Combustion

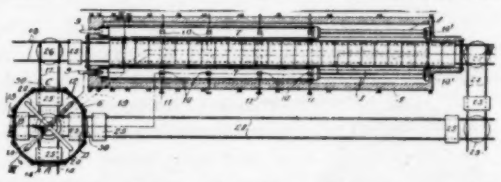
PATENTS

Continuous heating method and apparatus. CONRAD DRESSLER. 1,488,910, April 1, 1924. The method of heating mat. which consists in passing the material in two oppositely moving streams along side by side pathways through an elongated chamber and in subjecting the material in each stream during an initial portion of its travel through the chamber to the action of a set of convection currents of the chamber atmosphere wholly induced by the heat of the adjacent material in the other stream, and to the action of a second set of convection currents of the chamber atmosphere induced by a separate source of heat.

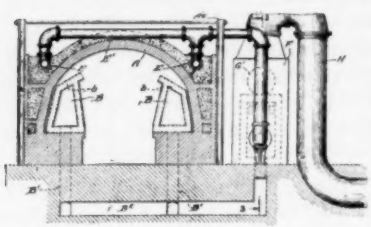


Tunnel kiln. HALVER R. STRAIGHT. 1,489,554, April 8, 1924. In a device of the class described, a tunnel designed to receive a series of movable cars, and to be divided into preheating, burning and cooling zones, and an adjacent and independently constructed furnace at each side of said burning zone, the adjacent wall of each having a series of corresponding openings, each corresponding set of which is provided with a loosely mounted refractory tube for conducting heated gases from the furnace to the said burning zone. In a device of the class described, a tunnel designed to receive a series of movable cars, and to be divided into preheating, burning and cooling zones, a car receiving vestibule at each end of said tunnel, mechanical means for feeding air under slight pressure to the cooling end of said tunnel, and mechanical means for simultaneously producing a slight vacuum at the preheating end, both of said means being capable of producing a constant flow of air under a constant pressure and at a uniform velocity.





Tunnel kiln. PAUL A. MEEHAN. U. S. 1,490,396, April 15, 1924. The combination with a tunnel kiln and its heating means, of an independent preheating chamber, together with means for heating the preheating chamber by the hot products of combustion from the kiln heating means.



Tunnel kiln. HARRY M. ROBERTSON. U. S. 1,490,433, April 15, 1924. The combination with a continuous tunnel kiln having

an outlet for products of combustion adjacent its entrance end and a burner inlet at a point remote from the entrance end of the kiln, of a recuperator connected to said outlet and a conduit for passing air preheated in said recuperator to said burner inlet comprising a portion extending longitudinally of said kiln and located above the latter.

Geology

The kaolin industry in Italy and Sardinia. U. ORZALI. *I. Lareizi ed Affini*, **2** [20], p. 21–3(1924).—A description of the location of various large deposits, their extent and grade of kaolin on the deposit. A large number of analyses are of various parts of the formations. The average analysis was: 40–50 Al_2O_3, 40–50 SiO_2, 10–15 H_2O-Fe_2O_3 is less than 0.5%. The analyses compared favorably with those of kaolins of other countries. A description of the deposits is geologically given. The process of washing the clay is described with various types and possibilities of the use of these beds of kaolin. S. S. C.

Bauxite, 1919–1921. *Imp. Min. Res. Bur.* (1924); *Min. Indus. of Brit. Empire and Foreign Countries* (1923).—This statistical report, aluminium, including bauxite and cryolite, gives rates of exchange, world's production; imports and exports of United Kingdom; Canada; and U. S.; with prices. O. P. R. O.

Arsenical ores (New South Wales). R. H. CAMBADGE. *Chem. Eng. and Min. Rev.* (Melbourne), **16,** 153(1923).—Arsenical mining ore operations have been active at the producing mines, and several promising outcrops in the New England district were located during 1923. A marked increase in the output of arsenic may be expected. O. P. R. O.

BOOK

MILLER, BENJAMIN L., AND SINGEWALD, JOSEPH T., JR.: **Mineral Deposits of South America.** New York: McGraw-Hill Book Co., Inc. 598 pp. $5.00 net, postpaid. (*C. A.*)

Chemistry and Physics

A comparison of the heating curves and quenching methods of melting point determinations. G. W. MOREY. *J. Wash. Acad. Sci.*, **13,** 326–9(1923).—The heating curve method is compared with quenching method which is used in silicate study. The quenching method is more accurate and by heating curve method the true melting point is on the more rapidly rising portion of the curve. Illustration of results given using sodium metasilicate where the results varied but 2° in 1100°C. S. S. C.

The residue from silica in rock analysis. M. AUROUSSEAU. *J. Wash. Acad. Sci.*, **13,** 330(1923).—The residue from the silica determination was analyzed of a andesite of Lassen Peak, Cal. and was found to contain:

		Of which in the original oxides of the rock this was	
Al_2O_3	13.46	Al_2O_3	0.4
Fe_2O_3	26.92	Fe_2O_3 and FeO	3.8
MgO	17.30	MgO	3.3
CaO	1.92	CaO	0.02
TiO_2	30.76	TiO_2	31.4
P_2O_5	1.92	P_2O_5	0.7
SO_3	7.69		

The total amt. of residue was 0.52% of original sample and by calculation it is possible to obtain the per cent of original not obtained by rock analysis. The complexity of the residue analysis raises a question of recovery and value by work involved to obtain results. S. S. C.

Recommended specification for ceramic whiting. Bur. of Stand., *Circ.* **152.**—This circular deals with lime used in making glazes, enamels and similar ceramic products. Ceramic whiting is really calcium carbonate, with or without a small amt. of magnesium carbonate, but it performs the function of lime. It should contain not less than 97% of carbonates, and should be very fine, so that 98% of it will pass a No. 200 screen. H. F. S.

Plasticity and elasticity. EUGENE C. BINGHAM. *J. Franklin Inst.*, **197,** 99(1924). —Plasticity and elasticity are closely related. The stress time curve for lead wire is given showing elastic deformation and recovery, pseudo-plastic deformation and recovery, and plastic deformation. Stress-strain diagrams are misleading beyond the elastic limit if the time factor is lost sight of. Stress-strain diagrams of iron, rubber, steel, zinc, copper and tin are explained. Glass is referred to. Instantaneous rigidity is the resistance to distortion extrapolated to zero time. There are objections to the use of the term resilience beyond the elastic limit, because the time element must be considered. Elastic after-effect is a kind of plastic flow. R. J. M.

The use of filter plates of sintered glass in the chemical laboratory. G. F. HÜTTIG. *Oesterr. Chem.-Ztg.*, **27,** 13; *Z. angew. Chem.*, **37,** 48–50(1924).—The glass-works of Schott and Gen. of Jena will furnish filter plates and filtering crucibles of varying porosity which are made from powd. glass. They can be used in qual. and quant. analysis, in making chem. prepns. and for the expts. of phys. chemistry. W. T. H. (*C. A.*)

A new combined viscometer and plastometer. E. C. BINGHAM AND H. A. MURRAY, JR., *et al.* *Proc. Am. Soc. Testing Materials*, **23,** II, 655–68(1923).—The times required for liquids or soft solids to fill successive portions of a calibrated capillary are measured on a chronograph. As the shearing stress varies along the capillary, the necessary data for a plasticity detn. or for duplicating fluidity detns. are obtained in less time than is often required for single fluidity detn. The method proves reliable when applied to castor oil over a range of temps. Preliminary measurements on a plastic paint give a lower yield value than was obtained with the Bingham and Green plastometer, but as the flow-shearing stress curve is linear it is suggested that there may be more than one régime of plastic flow. The paper is criticized at length by Green. E. C. B. (*C. A.*)

The thermal conductivity and specific heat of coal. F. S. SINNATT AND H. MACPHERSON. *Fuel*, **3,** 12–4(1923).—Because of the wide difference in results published in the past on the thermal condy. and sp. heat of coal, a systematic investigation of the banded ingredients was begun for the first time. The method for detg. the thermal condy. was that of Lodge (*Phil. Mag.*, **5,** 110(1878)) and Lees (*Phil. Trans.*, **184A** (1892)), the principle of which is described by Preston (*Theory of Heat*, 3rd. Ed. 1919). The sp. heat was detd. by Regnault's method of mixts., for which AmOH was most suitable. Values for 3 seams indicated that clarain has a condy. enough lower than durain (av. 0.00042 and 0.00052, resp., in C. G. S. units) to have a distinct effect on the rates at which the ingredients lose or gain heat and consequently to cause unequal stresses with change in temp. which may lead to fracture. Variations in the condy. of different types of coal were roughly proportional to the % ash, the following data giving the % ash and condy. $\times 10^4$, resp.: cannel 24.4, 69; Notts cannel 31.0, 62; shale cannel 33.3, 100; Smith shale 75.3, 110; Scotch oil shale 78.2, 130. In bituminous coals the condy. varied with the H_2O, the following data showing the % ash, % H_2O and condy. $\times 10^4$, resp., for clarain: Barnsley thick 1.0, 9.9, 37; Arley 0.8, 1.5, 43; Trencherbone 2.3, 4.1, 45. The av. *sp. heat of durain, clarain and vitrain* was 0.248, 0.246 and 0.252, resp., and of cannel, shale cannel, Notts cannel, Smith shale and Scotch shale 0.242, 0.226, 0.261, 0.210 and 0.217, resp. The results of the sp. heat show close agreement with those of Cole (*C. A.*, **18,** 577). The work is reported in an incomplete form, owing to its having been suspended. C. C. D. (*C. A.*)

Researches on the relation between the surface, mass and volume of certain crystals. K. HRYNAKOWSKI. *I^szy Zjazd Chemików Polskich*, **1923,** 14–5; cf. *ibid.*, 14.—It is shown that before the expression $dk/d\sigma.\sigma + K = F[\sigma.M_K - f(M_K/d)]$ can be applied to any crystal, it is necessary to obtain the value, P_r, of the function $f(M_K/d).P$; which is the surface of the given crystal. P_r must have as a minimum value that of a sphere of the same vol., P_K, and the ratio P_r/P_K approaches more closely to unity as the symmetry of the crystal increases. For a no. of cryst. substances this ratio ranges from 1.579 for Cu sulfate to 1.307 for sucrose. J. C. S. (*C. A.*)

Some consequences of van der Waals' equation. M. TZENTNERSHVER. *Z. physik. Chem.*, **107,** 81–96(1923).—For 0° the van der Waals' equation is $[p + (a/v^2)](v-b) = 1$. On putting $p = 0$, $(a/v^2)(v-b) = 1$ the roots of which are $v_1 = \infty$, $v_2 = (a/2) + \sqrt{(a^2/4)-ab}$ and $v_3 = (a/2) - \sqrt{(a^2/4)-ab}$. The last two roots are real if $a > 4b$. By substitution for a and b in this inequality of their values in terms of the crit. temp. and pressure the roots are real if the crit. temp. lies over the "limiting temp." 50.56°. When p is plotted against v for the van der Waals' equation, and as v increases from 0 there are first very large negative values of p rising to a max. while still negative then falling to $-\alpha$. On further increase of V, p jumps to $+\alpha$ and falls rapidly to a min., then rises to a max. and finally falls off asymtotically toward the axis $p = 0$. For gases with a crit. temp. under 50.56° the above min. of v falls at a positive value of p. For a gas whose crit. temp. is 50.56° the min. lies at $p = 0$ when $v = 2b$. For gases with a crit. temp. above 50.56° the min. lies in the region of negative pressure so that the curve crosses the axis $p = 0$ in 2 points. For example, with SO_2 which has a crit. temp. of 157.26° and $b = 0.002486$, the three values of v at which $p = 0$ are α, 0.003329 and 0.009831. For the general case of gases at any temp. the limiting temp., T_0, can be computed in the same way and is found to be $T_0 = 0.843T_k$, where T_k is the crit. temp. It is shown further that a *limiting density* and a *limiting mol. vol.* can be derived. F. L. B. (*C. A.*)

Surface films as plastic solids. R. E. WILSON AND E. D. RIES. *Colloid Symposium Monograph* (Univ. of Wisconsin), **1923,** 145–73.—Bubbles from some colloidal solns. show marked stability because the surface films are plastic solids rather than viscous liquids. Other solns. having low surface tension fail to give stable bubbles because they give only fluid films. The plastic solid films are of colloidal, rather than mol. dimensions, and may take hours to attain max. strength; solns. forming such films give erroneously high surface-tension results by the du Noüy and presumably other methods, the yield value of the plastic solid film being added to the true reversible surface tension. In liquid-liquid interfaces in emulsifying agents the production of such films seems to require much higher concns. than in surface films. Plastic solid films of this type are important factors in *lubrication*, being the determining factor in the oiliness of a lubricant, which reduces friction at low speeds and high loads. Discussion follows. J. A. (*C. A.*)

Forces regulating the size of colloidal particles. E. F. BURTON. *Colloid Symposium Monograph* (Univ. of Wisconsin), **1923,** 174–86.—The following aspects are considered: (1) slow rate of fall of small particles; (2) crystal forces at work in forming the nucleus of small particles; (3) role of surface tension in causing agglomeration of small particles; (4) mutual action of colloidal particles due to possession of electrical charges. Under (1) the following (see table) rate of fall is figured out on the basis of Stoke's law for silver particles falling in water (density assumed = 10.5, radius in table = r).

Surface tension contemplates surface with millions of mols., but there may be a lower limit to the size of surfaces to which surface-tension laws apply. Impurities and reaction affect particle growth; thus in alk. soln. NaCl tends to form octahedra, in acid soln. cubes. Expt. points to the existence of very formidable surface-tension forces

r	Velocity, cm. per sec.	Time to fall 1 cm.
1 cm.	200,000	0.000005 sec.
0.1	2,000	0.0005
0.01	20	0.05
0.001	2	5
0.0001	0.002	500
0.00001	0.00002	50,000 sec. = ½ day, approx.
0.000001	0.0000002	5,000,000 sec. = 58 days, approx.

acting on small particles. It seems safe to assume that the conglomeration of submicroscopic crystals is regulated chiefly by the fundamental surface-tension law, *viz.*, $(T \times A)$ tends to a minimum. Optical expts. indicate that colloidal particles are usually spherical. In general, cessation of growth seems to be due to elec. charges, which limit the concn. of suspensoid solns., and increase *Brownian motion*. Discussion follows.
J. A. (*C. A.*)

The thirty-two classes of crystal symmetry. J. W. EVANS. *Nature*, **113**, 80 (1924).—A table is published which shows a logical and convenient compilation of data regarding the 32 symmetry classes of crystals. S. K. A. (*C. A.*)

The importance of microanalysis for chemical analysis. L. MOSER. *Microchemie*, **1**, 1–4(1923).—Early in the 19th century the famous chemists were all analytical chemists but later it became the vogue to belittle analytical chemistry and carry out chiefly synthetic researches. Recently, analytical chemistry has been developing along new lines justifying renewed interest in research, and microanalysis represents one of these lines. W. T. H. (*C. A.*)

A new addition to the Soxhlet extraction apparatus. P. H. PRAUSNITZ. *Z. angew. Chem.*, **37**, 50–1(1924).—Filter plates of fused Jena glass may be substituted for the usual paper filter thimbles in the Soxhlet extn. app. These tubes are easily cleaned, and may be fused to the rest of the app. T. S. C. (*C. A.*)

The behavior and properties of magnesium oxide of different origins. M. LEBLANC AND K. RICHTER. *Z. physik. Chem.*, **107**, 357–402(1923).—An exceedingly detailed study is made upon 13 samples of MgO prepd. in various ways, as to purity microscopic and cryst. form, d., drying vol., ordinary and under pressure, amt. of dye adsorption, velocity and completeness of hydration, and the velocity of soln. in weak acids, etc. G. L. C. (*C. A.*)

BOOKS

Science Remaking the World. Edited by Otis W. Caldwell and E. E. Slosson. New York: Doubleday, Page & Co. 288 pp. $2.50. Reviewed in *Ind. Eng. Chem.*, **16**, 211(1924). (*C. A.*)

SVEDBERG, THE: **Colloid Chemistry.** Wisconsin Lectures. New York: Chemical Catalog Co., Inc. 230 pp. $3.00. (*C. A.*)

GREGORY, RICHARD: **Discovery or The Spirit and Service of Science.** American edition. New York: The MacMillan Co. 347 pp. $2. (*C. A.*)

HAMMOND, D. B.: **Stories of Scientific Discovery.** Cambridge University Press. 199 pp. $2.40. Reviewed in *Ind. Eng. Chem.*, **16**, 324(1924). (*C. A.*)

General

China clay and petroleum. ANON. *Chem. Age*, **10**[248], p. 9(1924).—China clay is used to bleach mineral oils replacing bone black. The clay is used as a powder and agitated with oil, being allowed to settle out leaves a clear liquor behind. The clay is dried from 300–400°C. The theory as to the quantity of clay necessary is discussed and the relation of the intensity of the color of the liquid to the absorption by the clay.

The clay should be added methodically to remove each gradation of color and the clay changed after each removal. S. S. C.

Settling of clay suspensions. A. E. SEARLE. *Chem. Age,* **10** [248,] 16–27(1924).—Suspension is dependent on size, shape, specific gravity, temperature of the water and nature of the electrical charge on the particles. Churning with air causes a suspension to settle due to a positive charge on the air bubbles. The use of an electric current is possible to clarify the liquid of the clay particles and still the same size of particle is retained, which is not true when a pptn. is added. S. S. C.

Microscopical examination of china clay. J. M. COON. *Oil & Colour Trade Jour.,* **65,** 457(1924).—China clay enters into such manuf. as paper filling, etc., it is therefore important to have it free from impurities; while chem. and mechanical analyses have their good purposes, a microscopical examn. is extremely valuable as a guide. Elutriation grades the sizes of particles to some extent, but it will not differentiate between the actual mineral constituents. C. prefers to exam. samples microscopically in a castor oil medium although water and Canada balsam may be used. A few milligrams of the sample are put on to a slide, and a drop or so of water added and carefully mixed. If oil is used as the medium, the slide must be dried, and an examn. made first with 1 in. objection, followed by $^1/_4$ in., and then $^1/_8$ in. The various minerals are then looked for, regarding all such as impurities. The paper is further illustrated with figures of the likely mineral constituents (*J. Roy. Mic. Soc.*). O. P. R. O.

Clay products situation throughout Canada. HOWELLS FRECHETTE. *Contract Rec. & Eng. Rev.,* **38,** 183(1924).—A review of mfg. and market conditions in the chief clay working centers of the Dominion based on personal visits paid in a recent survey by F., Chief, Ceramic Division, Mines Branch, Department of Mines, Ottawa. He also deals with some of the troubles which brickmakers experience particularly the fuel problem. Natural gas, a very cheap fuel, has been a wonderful asset to the clay working industries of Medicine Hat and Redcliff, which could not otherwise operate at all. The action of the Saskatchewan Government in establishing a ceramic laboratory and providing a consulting ceramic engineer has been a great assistance to the clay manufacturers of the province. O. P. R. O.

Electrical precipitation of solids in stack gases. SCHROEDER. *Feuerungstechnik,* **12** [9], 65(1924).—Groups fuel losses through the stack under three headings (1) Radiation and conduction, (2) escape of gases of imperfect combustion such as CO, (3) direct loss of fuel in form of soot, coke and ash particles. Tests on different types of boilers showed the loss under (3) to run from 10.6% to 29.7%. F. A. W.

Kaolin as a filler in paper making. ANON. *Indus. Australian and Min. Stand.,* **71,** 4(1924).—If china clay contains more than 2% of sand it is not suitable for use in paper making; in case of coated papers, the proportion of sand must not be greater than 0.1%; in fine grades of paper sand must not be more than 0.25%; in printing-paper the sand in the clay must not exceed 0.5%. Kaolin, added in moderate amount, makes paper more supple and facilitates its finishing; makes it more opaque and better suited for printing purposes; but clay added in too large proportions renders the paper soft and only slightly resistant to folding or crushing. Rigid rules for filling materials cannot be established, owing to the complication of factors that affect their application and which have a great influence on the proportion of the filling materials that remain in the manufactured paper. O. P. R. O.

Asbestos in the Union of South Africa. A. T. JUDGE. *Chem. Met. and Min. Soc. of S. A.,* **24,** 84(1923).—Four different varieties of asbestos are mined in the Union: The serpentine form of asbestos, known as *chrysotile* (a hydrated magnesium silicate, characterized by its high magnesium and water content); the amphibole varieties, *crocidolite* (a silicate of iron and sodium); *amosite* (a silicate of iron with little or no

sodium); *tremolite and asbestic* (which are silicates of calcium and magnesium). This article is well illus. O. P. R. O.

PATENT

Process of manufacturing antifriction bearings and compounds. CARL SCHMIDT. U. S. 1,482,414, Feb. 5, 1924. Process of manufacturing an antifriction bearing composition of a magnesia cement, consisting in mixing magnesiumoxyde (magnesia usta) with wood pulp previously soaked with oil, and chlormagnesialye, the resulting paste being dried to a cement of great sliding ability.

BOOK REVIEW

The Art of the Chinese Potter. R. L. HOBSON AND A. L. HETHERINGTON. New York. Alfred Knopf, 1924. $50.00. One edition limited to 500 copies for the United States. There will be no reprint in any shape or form.

This volume of 192 examples of pottery dates from the Han Dynasty to the end of the Ming. The 53 colored plates and 100 half-tone plates are selected, described and with an introduction by R. L. Hobson, Keeper of the Department of Ceramics and Ethnography, British Museum, author of "Chinese Pottery and Porcelains," etc., and A. L. Hetherington, author of "The Early Ceramic Wares of China," etc. The introduction gives a short account of the general development of the potter's art in China from about 200 B.C. to 1644 A.D., including certain observations based on knowledge recently acquired. The color plates are so good that the collector may compare his specimens with them and note important or minute differences. Each plate has opposite it a detailed description of the body, glaze, decorator, its height, its historical placing, and its owner. Such reproductions as these are the next best thing to living within easy reach of the few museums which have large collections of the originals. The study of ceramics is greatly vitalized in this way for those living at a distance. This book with the text of Mr. Hobson's "Chinese Pottery and Porcelain," are of inestimable value to the collector, the teacher, and the student. Mr. Hobson invites fine artistic judgment with a thorough historical knowledge. The binding is of striped dull blue and dull orange colored paper, with white velum back and corners and gold lettering. The volume measures 8 by $11\frac{1}{2}$ inches. MARY G. SHEERER.

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EDITORIAL

SCIENTIFIC RESEARCH AS AN ASSOCIATION ACTIVITY[1]

By H. E. Howe[2]

How slow industry has been to avail itself of the benefits of science and to give it a real opportunity to demonstrate its potentialities!

Many men have been signally successful because of their alliance with science. Others have stood by marveling but blind to the example set before them.

Pasteur, whose remarkable discoveries saved France a sum estimated as far greater than the indemnity paid to Germany at the close of the Franco-Prussian war, said, "In our century science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly the tiring daily discussions of politics seem to be our guide—empty appearances. What really leads us forward are a few scientific discoveries and their applications."

Ten or twelve years ago Robert Kennedy Duncan pointed out that "during the next five years the small manufacturer who is swept out of existence will often wonder why. He will ascribe it to the economy of large scale operations or business intrigues or what not, never knowing that his disaster was due to the application of pure science that the trust

[1] Presented at the Atlantic City Meeting, Feb., 1924 (General Session).

[2] Editor, *Industrial and Engineering Chemistry*, Washington, D. C.

organizations and large manufacturers are already beginning to appreciate."

It is true that many of our great discoveries have appeared to be by chance, but it can be demonstrated that these were made by trained observers systematically searching for new facts. Inventions are rarely made to order. To quote Dr. W. H. Bragg, a noted British scientist:

"It is easy and fascinating to suppose that a new invention is found as complete and clean as a nugget of gold, as unexpected and as unconnected with its surroundings, and finally as readily convertible into cash.

"The truth is very different. Science does not increase by the constant addition of new facts to old as a literary collection increases by the addition of new books or a museum by the addition of new specimens and curios. Science grows like a tree, which shoots out new branches continually and at the same time strengthens the old, always growing higher into the light. Like the tree, science needs wise cultivation. The nourishment of the tree, its training and pruning have their true counterparts in science. In both the fruits come as the reward of skill and labor."

To gain the greatest benefit from applied science, individual manufacturers should establish their own research and control laboratories. These laboratories should be well equipped and manned, made attractive places to work, be adequately supported and genuinely considered an intimate, integral, internal part of the organization. A laboratory can become more important than the sales or the advertising department. The Hadfield Steel Works in England have actually become attached to the research and control laboratory rather than the laboratory attached to the works.

Every industry finds it necessary to engage upon fundamental work, work in the field of pure science, upon which the so-called practical work or technology depends. Occasionally, indeed often, industrial laboratories undertake this work on their own account, but the work involved is so extensive that the individual corporation is seldom justified in doing it as thoroughly as is required.

The results of fundamental science research should not be left unpublished, since their disclosure can repay only in part the debt which any organization owes to science. Fundamental data do not of themselves alter the relative positions of competitors. It is the ability to apply the information that makes the difference between the success of these rivals.

An appreciation of these facts has led to associations engaging upon programs of scientific research. The great advantage gained early in the war by Germany, due largely to thorough organization among her scientific men and the confidence which her manufacturers have always had in science, impressed itself upon Great Britain. She saw the necessity of meeting such organization with an organization of her own scientists and set up an Advisory Council of Scientific and Industrial Research. This

council later became a department of the government, and known as the Department of Scientific and Industrial Research. This has been followed with some slight changes by the various English possessions. In Great Britain a million pounds was set aside by the government to encourage associations to put money into the work of organization, laboratory equipment, and staff. Pound for pound has been the plan for such organization and more than twenty-five associations have been formed, licensed, or are in process of formation. A further grant of a million pounds has been recommended by the government for another five-year period.

In America it has seemed best for associations to conduct their scientific activities without the aid of government money, for with the use of public funds there always goes a certain amount of necessary control which becomes irksome. Our trade associations have been formed without regard to scientific work and have undertaken this work only after a long period of education, during which it has been demonstrated that even competitors can work harmoniously on a scientific program.

A large number of the American associations began their work with standardization. The United States Bureau of Standards has prepared a report on the standardization of work going forward in 102 trade associations. Such work has been of real value.

We shall here recite the experience and methods of a few of the American associations.

California Fruit Growers' Exchange

The California Fruit Growers' Exchange, a coöperative, non-profit, non-capital stock corporation composed of 12,500 growers, organized a research laboratory primarily to develop methods for the conversion of the lower grades of citrus fruits into stable, salable products. The laboratory is operated at an approximate cost of $12,500 per year. Funds are obtained by an assessment of so many cents per box of fruit marketed. As a result of the work accomplished in coöperation with government agencies, the research laboratory has won an established place in the citrus industry.

The Magnesia Association of America

In contrast with the California Fruit Growers' Exchange, the Magnesia Association of America consists of only four manufacturers of magnesia products. Its purpose is the determination of constants and engineering data relative to the use of 85% magnesia as an insulating material, and the education of engineers, architects and plant owners to the importance of using insulating material in accordance with scientific data. The income of the Association is secured by a flat percentage tax laid on the actual goods shipped. The Association is operated on a budget system. Its

income has varied, depending upon the extent of activities, from a minimum of $20,000 annually to $125,000. This Association finds it advantageous to conduct its scientific work through a fellowship established at the Mellon Institute of Industrial Research. The findings of this research are given wide publicity, generally through the engineering and technical papers but to some extent through popular magazines and directly by mail.

National Canners' Association

Among the most successful has been the National Canners' Association. The fees for membership are one per cent per case of canned goods manufactured, and in addition to the support of the secretary's office and general machinery of the Association, including commodity advertising, the income is devoted to certain lines of informational work and scientific research. As conclusions are reached, valuable publications are issued. The laboratory carries on coöperative work in several important directions.

In some cases arrangements are made for the work itself to be done in laboratories outside the Association, but in coöperation with it. In matters of education, trade promotion, improved forms of reports, standards and research, the laboratories of the Association and the Association itself coöperate fully with both state and federal governments. Appropriations for single items of research have become as large as were the original allotments for the entire research program (about $30,000).

Clay Products Association

The Clay Products Association has undertaken research upon the study of the manufacture of salt glazed vitrified clay pipe. Results have not yet been reached, but it is gratifying to find that those interested in one of the world's oldest industries—ceramics—have found that it will be well to supplement many, many years of experience with scientific data.

In addition to research at Mellon Institute the Clay Prdoucts Association maintains a physical and chemical laboratory in Chicago where many problems directly affecting the use of their materials are studied. The Association is also engaged in the preparation of a handbook for the use of engineers, architects, and others, and feels that its scientific program is well worth while. The income of the Association is based on the amount of goods sold and the budget includes items for the scientific work decided upon for the year in question.

American Malleable Castings Association

The American Malleable Castings Association realized that the considerable number of inferior castings being made by the trade interfered decidedly with development of the market for malleable castings. The

Association formed a research committee, equipped a laboratory, secured a competent director, and began the work of so improving the products of every member of the Association that malleable castings would sustain a reputation for high, dependable, and uniform quality. The work has been going on for the last ten years, which is a testimonial to the high regard which the members of the Association have for research.

I believe the members who formerly made the best castings continue to do so, but the industry as a whole is far better off and the work of the Association in this direction has attracted attention in most of the countries abroad.

The Association spends about $150,000 per year in research. Work on control, in addition to research, is conducted at the expense of individual members for their benefit.

The various plants are visited each month to inspect castings and when quality is found to be deteriorating specialists go at once to see the trouble and endeavor to solve the problem.

Inspectors also see to it that the castings shipped by the producer are equivalent in quality to the test bars submitted to the laboratory.

A research committee meets the second Tuesday of every month in Chicago, followed by a regular meeting of the western members of the Association. The third Friday of each month finds the eastern members meeting in New York City. Joint meetings of eastern and western members are held quarterly in Cleveland.

American Gas Association

In the American Gas Association most of the income is derived from membership dues, of which there are two classes—company members and individuals. In addition, a charge is made for certain special service rendered to members and there is some revenue from the sale of publications.

The Association is rendering a very definite service to its member companies. It has upon its staff two members available for either field or installation work. Operating problems, industrial fuel development heating standards, the examination of gas appliances and gas consuming devices as regards fire hazards, efficiency, etc., indicate some of the lines of endeavor.

The Asphalt Association

The Asphalt Association is one of the newer industrial groups, having been formed in May, 1919. The members are assessed $100 annually as dues, but no additional payment is made by them. Contributing members pay a lump sum yearly, fixed by the Board of Directors in general conformity with the extent of business done by them and benefits to be derived.

This is generally an assessment varying from 32 to 40 cents per ton of paving asphalt sold. The Association was formed to increase the market for asphalt in paving, and in order to carry on its educational program and do constructive work, it calls upon science. This has to do not only with asphalt itself, but with the chemical and physical factors involved in its application, coöperation in designs for highway construction and the behavior of asphaltic types of pavement under various conditions of service.

Paint Manufacturers Association

The Paint Manufacturers Association of the United States and the National Varnish Manufacturers Association support an educational bureau. The educational bureau is supported by five-year subscriptions which range from $50 to $10,000 annually. These are voluntary upon the part of members of both associations and any others interested in the work. The funds for the bureau are kept distinct from the treasuries of the two associations.

The educational bureau has carried on research and experimental work for a number of years and published the results widely. It has studied special applications of paint and varnish and has developed new compounds, as for example, a special paint designed to reduce the fire hazard of wood shingles. When a new formula is devised and developed to the manufacturing stage, it is the custom of the associations to grant licenses for its manufacture to members of the associations.

Silk Association of America

The Silk Association of America has directed much of its attention to the conditioning and testing of raw silk. It has made important contributions to the subject and has performed a service in coöperating with foreign producers. This has led to silk being brought to our market in the condition best suited to our uses. Tests acceptable to both buyer and seller have been devised and there are many phases of silk production which have engaged the attention of the Association. These include testing of dyes, researches upon the fastness of colors to sunlight, fundamental work upon the physical constants of the individual silk fibers, etc. The conditioning house makes a charge for the work done and is owned by the Association. The work done is more satisfactory than was previously possible in a similar establishment privately owned.

National Association of Cotton Manufacturers

The National Association of Cotton Manufacturers has given extensive consideration to research in the cotton industry. Beginning with a research committee, upon which were cotton mill men and scientists, a larger

program has now been worked out. A research secretary has been employed who in addition to a certain amount of service work will travel in order to learn at first hand those problems confronting the various members of the Association which may be solved through applied science.

American Institute of Baking

The American Institute of Baking is one of the major activities of the American Bakers Association. The Institute is the outgrowth of an idea backed by one or two individuals who learned from personal experience what applied science can do for them. From a modest beginning the Institute has now advanced to the place where it owns a building, is giving short instructional courses, performs a plant problem service, and conducts research on problems fundamental to baking. A bulletin on the technology of the business is issued. Support has come to the project in such volume that a broad program has been made possible and is being put into effect.

This experience of the bakers is made even more interesting by the fact that by far the majority of commercial bakers would consider themselves unable individually to afford a laboratory or take on any expense which might not lead to immediate returns. Through the coöperative effort in which they are now engaged, the trade as a whole is able to avail itself of new principles and methods which otherwise would have been impossible.

American Society of Heating and Ventilating Engineers

The American Society of Heating and Ventilating Engineers devotes about $25,000 a year to its research laboratory. The funds are raised by popular subscription and the work is done in coöperation with the U. S. Bureau of Mines, Pittsburgh laboratory. More than twenty definite research projects have so far been undertaken. No tests, experiments or research are conducted for compensation.

Association of Manufacturers of Chilled Car Wheels

The Association of Manufacturers of Chilled Car Wheels has for its purpose the advancement of knowledge concerning the manufacture and service of car and locomotive wheels by discussion, investigations, and reports of experience of experts and of members of the Association. Information is gathered and distributed on the manufacture and service of car and locomotive wheels. When the organization was formed, every car had a special design of wheel. The Association has succeeded in standardizing to four types designed for cars of different capacities. These four take the place of about 175 patterns.

A consulting engineer is retained on full time and a physical laboratory

has recently been installed to further the work of the Association. There are 25 members of the Association.

Funds are obtained by assessment, based upon the capacities of the plants. Assessments in amounts of $5,000 are levied when funds are required. The total expense of operating the Association in a typical year was estimated at $40,000.

Portland Cement Association

The Portland Cement Association represents more than 90 per cent of the total production of Portland cement in the United States. In 1905, they began to discuss a research laboratory for the Association but a definite plan of action was not decided upon then and funds were not available. From 1916 on, the present activities of the Association were developed, having to do principally with scientific educational and promotional work. District offices are maintained to give service to users of cement, and through the structural materials laboratory research has been carried on and has proved its value to manufacturer and user alike.

A corps of engineers, chemists and assistants give their entire time to the work and the results are published in the form of papers presented by them before scientific societies and in bulletins issued by the laboratory for general distribution. The annual budget runs into several hundred thousand dollars, which includes the cost of maintaining the service engineers in the various district offices.

The research has to do largely with devising means for using local materials, and fundamental study on the part played by various components to concrete and cement, and the influence upon strength of such factors as temperature and moisture during setting, excess water in mixing, and similar factors. Assistance has been rendered in designing standard structures and in devising uniform rational construction practice.

National Lime Association

In its effort to give the public better information on lime to the end that it may be used more accurately and to follow up its educational work properly, the National Lime Association has found that in even so old a material as lime there is much need for investigation and research. This touches upon the properties of the materials produced in the different quarries and with different equipment. Much time is spent on the peculiar application of lime in more than 165 industries.

The investigational work of the Association is conducted not so much in its own laboratories as in coöperation and collaboration with other institutions which have a common interest in lime. A considerable amount of work is done through industrial fellowships in different institutions, this

work being directed jointly by the director of the Association and a representative of the institution concerned.

The data obtained are published and distributed among those interested, whether it be on lime for construction purposes, for agriculture, or for the chemical field.

Funds are secured by assessment on the product of each member in the organization, levied at so many cents per ton of lime produced, the amounts being fixed each year by members in convention assembled.

The Tanners' Council

The Tanners' Council of the United States of America includes nearly all the producers of various grades of leather. Previous to the war, a research laboratory was established which has since been reorganized upon a broader plane and encouraged to proceed with fundamental work as contrasted with service work on raw materials of one kind or another. The Council was instrumental in furthering a school where those in the industry might gain knowledge to make them better craftsmen. The council now has under consideration a comprehensive plan for the establishment of not only a school for craftsmen but for advanced students and for research through direct appropriations from council funds. An appropriation of $110,000 has been made recently for a new research laboratory.

The Refractories Manufacturers Association

The Refractories Manufacturers Association has been engaged in research for over five years, the original yearly appropriation having increased about 500 per cent. At first, only problems of general interest were studied and this policy was followed for about one year. At that time it became evident that many of the research problems of the various companies required special study. These studies can be made by following certain definite procedures, but the results are affected by operating conditions at the various plants.

The refractories industry, especially that branch which is devoted to the manufacture of fire-clay brick, does not work with a standard material. The physical properties of the clays vary as does the process of manufacture. It is this situation that limits the application of many of the results that may be obtained by research. Consequently, it was decided to make the research facilities of the Association available to the members by the payment of a fee necessary to cover the expense of an individual investigation. This latter field has been most profitable and popular, for the results are immediate and have a definite application. The experience gained by studying the same problem at different plants has been invaluable and often has made possible the expression of an opinion or

recommendation without additional study as the problem continues to arise.

There is an extremely large field in this industry for the study of conditions under which the product is used. As these studies progress certain facts become evident. In some cases, the product is used with shameful ignorance as to how it should be treated, yet when ultimate failure results it reflects upon the producer. Careful study has developed information on many of the evil practices that are common. On the other hand, certain raw materials cannot be used for many purposes; the shrinkage may be too high, the refractoriness too low, or the strength insufficient. In other cases, complete knowledge of service requirements enables the production of suitable ware.

An unforseen development of this plan has been in connection with matters of a more business-like nature. An accumulation of extensive data is of great benefit in many of the every day problems that come up, regarding specifications, tariff matters, trade development, and similar examples. The centralization of data regarding similar products permits the formulation of policies that would otherwise remain undeveloped under conditions where each manufacturer is forced to protect his own interests without knowing how others may be affected.

American Meat Packers Institute

The achievements of scientific research in the packing industry have become a classic and are often used to illustrate how exceedingly profitable research can be made in commerce. Every packing house of any consequence maintains a research and control laboratory. In view of these facts it is particularly interesting to note that a concerted movement has been initiated by the Institute of American Meat Packers looking toward the establishment of an Educational Institute. It is recognized that there is at present duplication of research work, that there is a limitation of research to such lines as may be expected to return a quick profit, that the individual companies—and there are 257 of them in the Institute—have their development limited by their own experience, that no effort has been made to systematize this industrial experience, and that the future is limited by the progress of the present. The industry is looking toward the establishment of a central distinctive home where technical men may be trained to succeed those now active in the packing industry, where by providing facilities for a broad training the executives of the future may not be specialists in such narrow fields as many departmental executives of the present régime are known to be.

The Institute is to become an organization which will combine the activities of a research institute, an educational center, a trade association,

and an industrial musuem. To quote from the plan submitted by the Institute Plan committee, of which Thomas E. Wilson is Chairman:

1. As a research institution, it should:
   a. Develop and systematize a body of scientific and practical data for the service of the whole industry.
   b. Carry on agreed researches into new scientific and practical problems common to all packers, without infringing on research along individual lines being done by specific companies.
   c. Conduct experiments on the extension of products and reclamation of materials (except where such experiments would infringe on original work done by some individual company.
   d. Collate and disseminate information concerning discoveries and developments having relation to the packing industry, without invading material developed by particular companies.
   e. Conduct merchandising surveys and commercial research work.
   f. Discover waste and means of eliminating it.
   g. Test materials and equipment offered to the industry.
2. As an educational institution it should do at least three things.
   a. Provide broad but specialized collegiate education for young men intending to enter the packing industry, just as the Colorado School of Mines provides such training for young men expecting to begin their work in the mining industry.
   b. Furnish special training to intermediate sub-executives (prospective departmental heads) of promise already engaged in the industry.
   c. Conduct a continuation school for plant employees and junior office help.
3. As a trade association, it should continue to do what the Institute is now doing in this direction.
4. As an industrial museum, it should provide space for permanent exhibits of models showing modern packing-house operations, specimens and processes; and it should rent out space for exhibits of materials of industrial value, and for a permanent exhibit of packing house machinery and supplies—a sort of scientific museum and centralized market place, a gigantic permanent show window, conveniently located (being at Chicago) where packers from all parts of the country may come and view samples before making purchases and installments.

Plans for Coöperative Research

Many other associations are engaged in coöperative research on plans as diversified as are the industries represented. Many associations prefer to use their own laboratories, man them, and direct the work. Other associations begin by supporting a fellowship at one or more of our uni-

versities. Some rely upon the excellent facilites of some of our commercial laboratories or consulting engineers. Others make existing laboratories in plants available for the problems assigned and may begin with a sort of informational clearing house on existing knowledge and the state of the art as disclosed by the literature. Societies themselves may be formed, like the American Bureau of Welding, and the Crop Protection Institute, where all interested may meet on common ground and apportion the work, oversee it, and through the means of committees obtain funds from members and conduct experiments without actually establishing a separate laboratory.

Another plan is that of coöperation with various government laboratories. Research associates are placed in these laboratories under the direction of the head of the bureau but with the program arranged with the assistance of an advisory committee representing the industry. At the Bureau of Standards in addition to research associates placed by single companies, scientists are maintained by the National Glass Containers Association, the Hollow Building Tile Association, Associated Tile Manufacturers, and the National Gypsum Association.

At the Bureau of Mines we find as coöperators a number of Chambers of Commerce, individual companies, universities, and public service corporations. The Southern Appalachian Coal Operators Association and the American Society of Heating and Ventilating Engineers also work with the Bureau of Mines. The Heavy Clay Products Associations and The Refractories Manufacturers have coöperated with the Bureau of Mines in an extensive survey of possible economies in kiln firing. In general the Bureau contributes the time of specialists, the equipment in housing, and other substantial assistance.

The results in all cases where government coöperation is involved are made public at the conclusion of the work.

The Forest Products Laboratory, the Department of Agriculture, and its various bureaus, and other government agencies are frequently available to organizations conducting research where the public good is involved.

Conclusion

It has been shown that research can be successfully conducted by the association plan, whether the association be composed of a small or a large number of individuals, that there is a precedent for nearly any type of association; and that there are many methods for securing research funds. In general these are based either upon the gross business done, the capitol stock, the number of employees, items of equipment, or the number of packages of products shipped. Voluntary contributions form another somewhat less uniform basis.

There are facilities and plans for carrying on a research program to suit any association activity, and a start can be had with a director of research who can survey the field, tabulate the problems and set up an informational clearing house, if funds are not available for a more extensive program. As money becomes available, fellowships can be established, special problems assigned to individual laboratories, and in time if desirable, a laboratory can be set up and maintained by the association for study exclusively upon its problems.

There is still another possibility. I refer to a technical society, such as the AMERICAN CERAMIC SOCIETY, coöperating directly with trade associations in planning, supervising, and even executing a carefully selected scientific program. The SOCIETY could in fact be the Ceramic Research Institute in which the several Ceramic Trade Associations could have a common interest and control, and the most economic directing of their technical and scientific problems. This would be employing a going organization, well organized, productive and rapidly growing in strength which the Ceramic Industries are even now supporting and governing. This would merely be employing that which the ceramic industries already have. The only thing necessary to make the AMERICAN CERAMIC SOCIETY directly and immediately available to the several ceramic trade associations is a change in the scheme of the SOCIETY organization and control of finances whereby the trade associations would be the controlling agents for their firm members, jointly with the several other ceramic interests which perhaps could not readily be represented through trade associations. This sharing in control of the affairs of the SOCIETY by trade associations could be arranged by constitutional provisions so that the individual members would gain rather than lose in their rights and benefits of membership. It would affect that happy union in service of the financial and the technical industrial executives.

WASHINGTON, D. C.

PAPERS AND DISCUSSIONS

LONGER LIFE OF OUR TANKS[1]

By C. A. Modes

What is meant by the life of a glass furnace?

It is the period of time during which a furnace will furnish a fixed tonnage of glass of quality that will permit a maximum production of articles which measure up to the standards required by the consumer. The producer's interest lay in the attainment of certain quality, clarity, luster and strength. Quantity production requires a working quality of the glass that will not slow down operations, and after the ware is made, will not be lost due to strains.

We shall consider only glass tanks operating under modern conditions, supplying glass to automatic machines. This operation is intensive, twenty-four hours of the day, and six to seven days of the week.

From the time the glass is given to the machines there must be no interruption of flow from the furnace. This condition demands that the temperatures must be kept constant while the raw materials are being brought into solution and that while the furnace is "under load" certain "working temperatures" must be maintained. The results to the glass in the bottle are serious with the most perfect batch if the proper temperatures are not maintained.

Money is invested in the construction of a furnace to produce the maximum number of pieces per twenty-four hours. Each piece has a fixed sale value which must cover such charges as tax, cost of construction, raw material, fuel, maintenance, labor, selling costs, etc. Given a furnace which will consistently furnish a given quantity of good glass per twenty-four hours there is a potential profit if it can be made to produce 110% or 115%. It is a tempting opportunity that soon brings about an overload. The larger quantity of raw material requires a larger heat input to maintain the required tank temperatures. Indeed the working temperatures must be higher if there is to be a shortening of the time interval between the introduction of raw materials and the drawing of refined glass. In this we may for a time succeed, then the results of overstraining and overheating of the tanks begin to show. The furnace has not withstood this more severe treatment. Another repair bill has to be paid. Production is halted which in turn may mean loss of customers. Will the year's profit and loss statement reflect the anticipated earnings from this over-burdening of the tank?

The question of how long a modern machine furnace should last is one that cannot be determined without careful consideration of all these relating factors. Some basic units of production will have to be adopted,

[1] Presented at the Atlantic City Meeting, Feb., 1924 (Glass Division).

for example an average producing capacity of twenty-five tons of good glass every working day for a period of twelve months. In this standard schedule, allowance would have to be made for the time required to repair the furnace, and for the gradually decreasing furnace efficiency due to erosions of the materials, which would require heavier loads and more heat input when the furnace was first started. At the end of the twelve-month period just as good a glass and as good ware would have to be made from this furnace as at any time.

Careful record would have to be made of the construction, hourly temperatures, fuel used, glass produced, batch melted, temporary repairs, minor maintenance, etc. The time taken to heat from 70° to melting temperature and the methods used would have to be known. These conditions and practices vary quite widely in different glass plants, each operator believing his to be the only safe procedure. And they are justified in their opinions by the results they obtained but nevertheless without a standard basis of rating it is impossible to make comparisons on "life of tank."

Unfortunately, however, there are many influencing conditions and factors which cannot be forseen in the carrying out of the most exact procedure. Even when the furnace is rebuilt with satisfactory block the chances are it will not operate with the expected efficiency. We are confused and have nothing to offer but opinions in lieu of explanation and this is not the way to solve the question. The block-maker is blamed as is the builder and the operators. We try again. Somewhere in the construction and operation we varied widely from the specifications.

Two factories both using blocks of the same make, one is convinced that a 12-inch and 15-inch thick block is the best while the other believes a 10-inch and 12-inch block is the best. The first plant condemns the quality of the blocks on the basis of short life on the furnaces, while the second plant has success with the thinner blocks and produces more glass per square foot of melting surface than does the first plant, temperatures used by both being the same.

In a certain plant two furnaces are operated, one furnace by a thermal engineer using all the refinements and means of control possible. The other furnace of similar construction operated without these refined control devices, produces as much good glass per pound of fuel as does the first. In this case the furnace design and construction are the most effective factors and if given the same ratio of heat input and same charge of glass batch per day, their productiveness will be equal.

One attractive problem is the small amount of heat used in the actual melting of a pound of glass, the high heat loss at the exterior of the furnace, and suggestions of how to conserve more of the heat for glass making. The answer is proper insulation. There are certain portions of our fur-

naces that can be insulated without shortening the life of the furnace, and there are other portions which, if insulated, would rapidly deteriorate.

Recently I saw an attempt at insulation of the high temperature portion of the furnace. I would not recommend any one to repeat this experiment.

Makers of refractories frequently offer a new idea in shape, size or make of block as a cure for tank failures. Unfortunately the glassmaker must put the material to actual test before either the blockmaker or he knows the positive results. If it is a success the blockmaker is elated and tells the other glass makers; if a failure, he is silent and the glassmaker is sorry.

There is too much empiric in the production of tank blocks. Blockmakers, however, are sincere in their efforts to furnish the longest life blocks.

By "blocks" I mean blocks used below the glass line. The refractory material used in construction above this flux line if properly constructed, is not a factor in the life of the furnace. It is below the flux line where our troubles are had. The blocks above the glass line may be and in most cases should be of quite different materials than those used in the blocks with which the glass is in contact. This requires different clays and different mesh grog, which results in different density and coefficient of expansion. The blocks used in contact with the molten glass are made to withstand high temperatures and the erosive action of the batch materials. Careful attention must be given this portion of the furnace throughout the life of the furnace.

The reported "long life" of some furnaces is creditable to the furnace having been operated much under capacity and the "short life" of other furnaces is chargeable to poor construction or poor handling during the heating-up period.

Each plant has its problems and I cannot see the possibility of anyone making specific recommendations for longer life of furnaces until agreement is had on what the expected time a furnace should operate, and what shall be a normal quantity and quality production of glass. Decision can be made only by a group of reliable men conscientiously considering materials and construction. They would have to assemble a large amount of actual operating data. This would require time and the confidence of furnace operators.

ILLINOIS GLASS CO.
ALTON, ILLINOIS

DISCUSSION ON "EXACT NOTIONS OF FLUORINE ENAMELS"[1]

(Reply to J. E. HANSEN'S Discussion)

CHARLES MUSIOL: Mr. Hansen believes that no loss of SiO_2 is visible in his examples, notwithstanding the fact that the fluorine is entirely driven out as SiF_4 on which the calculations were made.

[1] C. Musiol, *Jour. Amer. Ceram. Soc.*, **7** [2], 105(1924).

Let us take again the analysis "A" and "C" and also "A" "Cx" given by Mr. Hansen and let us examine them after their transformation into "substractive" analysis, according to our method.

Let us first suppose that the analysis "A" should not have undergone any change; it should have remained "A." In consequence we should have:

$$\frac{\text{values of "A"}}{\text{values of "A"}} = 1$$

it is to say that these quotients would have remained equal to the unit.

TABLE I

	"A"	"C"	"Cx"	$\frac{\text{values "A"}}{\text{values "A"}}$	$\frac{\text{values "C"}}{\text{values "A"}}$	$\frac{\text{values "Cx"}}{\text{values "A"}}$
Na_2O	17.40	18.34	18.10	1	1.054	1.040
K_2O	1.69	1.78	1.79	1	1.054	1.059
CaO	5.59	5.89	5.93	1	1.054	1.060
MnO	1.03	1.08	1.09	1	1.050	1.058
CoO	1.14	1.20	1.21	1	1.053	1.061
B_2O_3	13.85	14.60	14.32	1	1.054	1.035
Al_2O_3	5.70	6.01	6.05	1	1.054	1.061
SiO_2	50.90	50.50	50.90	1	0.992	1.000
F_2	3.68	...	...	1	...	...
	101.55	100.00	100.00	...	...	...
$-O$	1.55	...	...	1	...	...
	100.00	100.00	100.00			

Let us look now at the quotients of the analysis "C" and "A" and of the analysis "Cx" and "A." We immediately see by the difference of the quotients that in the first case there is complete disappearance of fluorine and loss of SiO_2, and in the second case complete disappearance of fluorine, loss of SiO_2 and a feeble loss of Na_2O and of B_2O_3.

This proves without any doubt that the mere "chemical data" are not sufficient to conclude and that they may, without the mathematical proof, make the chemist the victim of his fallacy.

I think Mr. Hansen is wrong when he excludes the mathematical means from chemistry, for both methods must complete each other.

Any enamelist knows that any mixture of chemical products, applied to the enamel-batch, put into the melting-furnace consists of two parts:

1. The former, which gives the enamel generally represented by a molecular formula, and

2. The latter, which containing products such as water, organic bodies, different gases, etc., evaporates or disappears, forming perhaps new chemical combinations, and is not represented in the formula of the enamel.

My article only treats those phenomena which refer to the first part of

the enamel-batch, *i. e.*, to the enamel and it has not at all touched the question of the second part. Therefore, the statement that the "fluorine escapes as such," *i. e.*, from our enamel-formula, is correct.

What may occur with this fluorine in status nascendi when it gets into contact with the second part of the enamel-batch, is quite another question, not discussed by my article.

For this reason I am obliged to reject the sentence of the abstract expressing that "the fluorine disappears during the melting process as F_2," because I did not pen that myself.

To the question of Mr. Hansen as to where I obtain the oxygen to form the CaO of CaF_2, I wish to make reference to the reaction which takes place in submitting the fluorspar to red heat in a steam-atmosphere, according to the formula: $CaF_2 + H_2O = CaO + 2HF$.

The presence of water in any enamel-batch is to be found under the form of humidity, hydrated water, water of crystallization coming namely from the boracic compounds when the enamel is not boronless.

Let us take as examples the typical American enamels published not long ago by Mr. Wolfram:

100 kg. of ground-coat-batch at 32% borax contains 15 kg. cryst. water
100 kg. of white enamel batch at 25.5% borax contains 12 kg. cryst. water

These quantities of water are more than sufficient to satisfy the demand of oxygen which should be necessary for the substitution of the fluorine.

Whether the fluorine disappears under the form of SiF_4 or under any other form constitutes an academic question which may be of some curiosity to the chemist, but which is not useful at all for the enamelist. The vital question for the latter is to know whether or not the partial disappearance of the fluorine always involves a decrease of SiO_2, as certain chemists pretend.

H. H. STEPHENSON: Mr. Hansen has pointed out, I think very justly, the improbability of the element fluorine escaping. The following list includes most of the possibilities, some of them very remote and in fact hypothetical.

(*a*) From the enamel: SiF_4, BF_3, HF, NaF, KF, SnF_4, SbF_3, TiF_4, and their double compounds.

(*b*) From the atmosphere: The formation of a compound of F with O or N or both, nitrides, NOF, NH_4F.

(*c*) From fire gases, if present: The formation of a compound of F with a saturated or unsaturated carbon compound (cyanamides, etc.).

Before seriously considering (*b*) and (*c*), it would have to be shown that an enamel behaves differently when heated in a vacuum or in a quite indifferent gas to what it does in air. But in view of the fact that almost all of the elements present in an enamel are known to form nitrides at high temperatures, and that nitrides with H_2O form ammonia, the following

equations do not appear to me impossible as temporary and catalytic phenomena.

(1) $CaF_2 + N_2 + H_2O = CaO + 2NH_4F + N_2O_3$.

(2) NH_4F dissociates, the HF escaping or attacking SiO_2 or B_2O_3; and $2NH_3 + N_2O_3 = 2N_2 + 3H_2O$, as in the preparation of N from NH_4NO_2.

Thus one might look for HF, NH_3 and N_2O_3 in the exit gases.

In the (*a*) list, KF boils at 1458°C and NaF at 1705°C; temperatures far above the enamel burn. Their double compounds with other fluorides may be possible.

The problem however has been settled under actual industrial conditions in favor of SiF_4 (excepting BF_3). How does sodium silicofluoride come onto the market in fairly large quantities and at a reasonable price? Simply because it is a by-product of the artificial fertilizer industry. The phosphate rock contains enough silicates and fluorides as impurity to make the escape of SiF_4 noxious and therefore prohibited by law in most countries. It may be objected that this reaction is an acid reaction in presence of sulphuric acid, while the enamel conditions are alkaline. This is not strictly true. A glaze slip may be alkaline, but at high temperatures SiO_2 makes all kiln reactions acid reactions.

Thus SiF_4 and BF_3, formed directly or catalytically, remain the leading probabilities. A well-equipped spectographer would settle the matter in a few minutes (see "Practical Spectographic Analysis," No. 444, Bureau of Standards, Scientific Papers).

J. E. HANSEN: With regard to Mr. Musiol's reply to my discussion of his paper on "Extract Notions of Fluorine Enamels," may I state that I have no wish to exclude mathematical interpretations from chemistry, but that the point which I wished to emphasize in that discussion, and which I still wish to emphasize is that the chemical analysis of the fritted enamel and any mathematical relationship which may exist between the constituents of the enamel in the raw batch and in the fritted condition *are not sufficient in themselves* to show *in what form* the volatile constituents of the batch escaped from it.

The possibilities for various chemical combinations to be formed in the melting of an enamel batch are so numerous, and are subject to such complexities, that even with a combination of chemical and mathematical relationships, no proof can be considered a real *proof* until it is substantiated with chemical data showing the quantity and composition of the gas evolved during the melting process.

Furthermore, all the enamel constituents, when in a molten or liquid state, have a certain vapor pressure, great or small, depending on their individual characteristics and upon the temperature of the smelting furnace. This vapor pressure results in volatilization losses of each and every material, to a greater or lesser extent, which in turn alters the chemical analy-

sis of the resultant fritted enamel, and likewise alters any mathematical relationships derived therefrom.

I am still unable to reconcile Mr. Musiol's statement that "fluorine escapes *as such*" (the italics are mine) with his denial that "the fluorine escapes during the melting process as F_2." Certainly according to the usage of the English language, "*as such*," in this case, can mean only "*as fluorine* (F_2)," and it cannot mean fluorine in combination with any other element.

REFRACTORIES QUESTION BOX

E. E. AYARS, EDITOR

1. Does the grinding (coarse or fine) have anything to do with the resistance of a fire-clay brick to spalling?
2. What difference is there between the properties of a soft mud machine made and a hand made brick?
3. What is the best method of sampling fine ground fire clay for testing? Discuss straight clay and cement mixtures.
4. Can a customer form any judgment of the quality of a shipment by a test made on one brick? If not, how many samples should be used?
5. Can an iron free clay brick be made for blast furnace service?
6. Will results in service justify the expenditure and added cost necessary in order to make fire-brick mixes from definite percentages of definitely sized clay grains?
7. What effect do soluble salts (such as show on red burning clays as scum) have on the refractoriness of fire brick? Are the silicates formed with such salts in burning of low refractoriness?
8. What effect do sand and air inclusions (commonly called sand cracks or molding cracks) incident to hand molding, have on the service of hand made fire brick?
9. What is the cause of rapid failure of fire brick in the checker work baffles of oil-fired boilers, subjected to a temperature of 2300°F but against which the oil flame does not impinge? The failure consists of premature vitrification and carbonizing with subsequent fusion. Is this a result of subjecting the brick to a reducing atmosphere?
10. What is the reason for the more rapid failure, at a lower temperature, of fire brick subjected to reducing atmosphere, than will obtain with the same brick under oxidizing conditions?
11. What is the relative spalling tendency of fire brick under reducing and oxidizing conditions, respectively?

Question

Does the grinding (coarse or fine) have anything to do with the resistance of a clay brick to spalling?

Discussion

There are certain finely ground fire brick that resist spalling very well and there are other coarsely ground fire brick that do not, but when other conditions are the same a coarsely ground brick has a higher resistance to spalling. The finely ground brick that stand up well are invariably made

from very refractory clays or clays that do not vitrify at the furnace temperature. The coarsely ground brick that spall badly usually have poor mechanical strength or else are made either from dense burning clays or clays of low refractoriness. The fine ground brick that stand up well can be improved in many cases by coarser grinding; the coarsely ground brick by increasing the strength in some cases or by reducing the content of dense burning clay in others.

I think it was mentioned that the coarse grain brick had a higher spalling than finer grain brick and when these bricks spall it tends to break up this thin film of coarse and a chunk of brick would fall out. This fine grade brick did not spall at all—it wore down very gradually until it was about one and one-half inches in thickness, red hot on the outside. These bricks were tested in an alkali furnace.—RAYMOND M. HOWE.

In almost every paper written on the manufacture of brick for use in malleable iron furnace bungs, it is stated that the best bricks for this purpose are of coarse grind, open texture and light burn. The grinding exerts a great influence on the resistance of a clay brick to spalling but the grain size should be within certain limits. Brick that are too coarse, spall just as readily as those that are too fine.

The following screen analyses are offered as evidence:

	(1) Per cent	(2) Per cent	(3) Per cent
Retained on No. 10 sieve	27.8	19.4	3.7
Retained on No. 20 sieve	18.7	19.8	22.4
Retained on No. 40 sieve	9.2	10.4	14.0
Retained on No. 60 sieve	4.7	5.2	7.4
Retained on No. 100 sieve	4.0	5.3	7.1
Passed through No. 100 sieve	35.6	39.9	45.4
	100.0	100.0	100.0

Samples No. 1 and No. 2 were made from the same type of clay by the soft mud, repress method and given the same heat treatment. Sample No. 3 was made from the same type clay by the dry press method.

Sample No. 1 gave about four heats in service.

Sample No. 2 gave about twenty-two heats in service.

Sample No. 3 gave thirty-three heats in service.

These results seem to indicate that coarse grinding is not the way to overcome spalling in brick made from Kentucky semi-flint clays.—C. E. BALES, Louisville Fire Brick Works.

In conducting some tests on kaolinitic fire clay we found that there was a difference. Those clays did not vitrify. We found that the difference between two bricks of exactly the same composition, one over an 8 mesh screen,

the other over a quarter mesh screen, without any effort to control the percentage except with the natural differentiation of a screen, would make that difference on exactly the same brick. In the average spalling test we only got 3 heats on the 8 mesh, where we got 15 on the quarter mesh.

The manufacturers of Pennsylvania brick are unanimous in saying that a coarse grain brick is the best resistance in spalling in service and in spalling tests besides.—A. F. GREAVES-WALKER, Stevens, Inc., Stevens Pottery, Ga.

It does not seem as though we should be expected to draw conclusions from one article. Perhaps in this case the coarse ground brick would give a very poor value, the mechanical strength being as big a factor in the failure as what you might term real spalling. It seems as though there is a pretty fine distinction there to determine whether the spalling is due to heating and cooling or whether it is due more to a squeezing, a pressure effect, that you might have. With Pennsylvania clays—there is no question but what a finely ground brick can be bolstered up by a coarse grinding; on the other hand with a clay such as the sandy clays of New York, I do not believe you could change their resistance to spalling a whole lot by changing the size of the grain—that is, in actual service, because those bricks are so low in impurities that vitrification probably does not take place very rapidly and when they finally go, they go with a bang. The New Jersey brick is pretty finely ground and they certainly can stand heating and cooling all right. So you get as many different results as you have methods and clays.—F. A. HARVEY, U. S. Refractories Corp., Mt. Union, Pa.

Question

What is the best method of sampling fine-ground fire clay for testing? Discuss straight clay and cement mixtures.

Discussion

In the case of very fine materials like clays and cements, we usually open, in a carload of cement for instance, about twenty-five bags. We have a long sort of a tube, we ram the tube away down into the bag and take a sample out with that tube. We take the twenty-five samples and mix them and pour it down to whatever we want to use it for, sieve tests, etc. In case of bulk shipments we do not get very much fine stuff, but when we do we bore down into the car. Of course it has to be more or less surface sample. We cannot go very deep. In the case of some of our chrome ores, we dig trenches from one end of the car to the other, and clear to the floor.—C. E. NESBITT, Carnegie Steel Co., Pittsburgh, Pa.

In the case of some refractory clays that we suspected of varying greatly, and to prove whether they did or not, for every tenth shovel full we took

out a small shovel full, like a hand sample of material, and threw it aside—just loading out of a box car. That resulted in about four barrels of clay to the carload. We sampled that down and seemed to be able to catch it pretty well that way and it did not entail much loss. Loading in wheelbarrows, loading out of the car, they took just a small shovel full and dropped it into a barrel at the end of the car.

CHAIRMAN: Was that ground clay?

MR. ROSS: Some of it was as large as two inches.

CHAIRMAN: Was the sample representative or did the man who took that sample get more lumps than anything else?

MR. ROSS: I stayed on the job for three cars myself and got two men trained so that they would follow pretty well. They did not take lumps—they took average of the material. It ran some but not very much. —D. W. Ross, Washington Clay Pot. Co., Washington, Pa.

CHAIRMAN: In the shipment of such materials as ground ganister which have various percentages of clay in them for patching and bottom work, the clay goes to the bottom of the car and when it is unloaded very often the material is separated enough so that the mixture in the top of the car has not sufficient clay for plasticity and that at the bottom has a very low fusion compared to what is required. Every manufacturer has his own method of taking care of that. Sometimes it amounts to a bad complaint and expense but on the average I do not think it is customary to caution the consumer about the handling of that clay.

MR. HARVEY: It seems to me the only method which would be fair, of settling that, would be the one suggested by Mr. Ross, by which you take a small portion out of every tenth shovel full or wheelbarrow load, or however it is you are emptying the car.

MR. WALKER: Mr. Harvey has had a great deal of experience in materials of that kind. Couldn't he say something about it?

MR. HARVEY: I am responsible for that question. I wanted to bring out exactly what has been brought out by Mr. Nesbitt, that in the case of bulk shipments it is usually surface sampling.

In loading a car of finely ground material you have, of course, a mixture running from 8 mesh, or 30 mesh, down to 200 mesh. The coarse stuff will run off the surface of that car and you get a bigger proportion of coarse material. The test on that sample will be entirely misleading as to the average content of the car. We have recently developed a method at our own plant which is simpler than the one Mr. Nesbitt uses in the case of bag shipments. We have made a tube about eight feet long which is split along one side the entire length and has a handle through it. We go over the top of the car, push the tube clear to the bottom of the car, give it a full turn and pull it out and use that as an average sample, a cross-section,

at that particular place in the car. I do not know whether that is the final answer on sampling bulk shipments—it possibly is not, but certainly it is much better than getting a surface sample of a car of fine ground material.

If possible, a small amount of the fire clay should be taken at regular intervals as the car is being loaded at the manufacturer's plant. This should then be averaged and about a 10-pound sample taken for testing purposes.

If sample has to be taken after shipment, about twelve samples should be taken from different parts of the car and at least a foot below the surface. These are mixed, and a small sample for testing taken from the average.—E. N. McGEE, The Semet-Solvay Co., Syracuse, N. Y.

MR. PHELPS: We have in our laboratory what we call medium sample. We make borings in the top and vibrate those borings in a bottle by an electric vibrator. We vibrate each boring. We set the bottles along in a row and we can get a medium sample. We used tall bottles small in diameter. We take the center of the borings from the car, place them in the bottle and fill the bottle with water. We set the bottle on the top of the electic vibrator, hold the top of the bottle with the hand. The vibration is the same but a very quick medium. The finer will come to the top, medium fine stay to the center, and sometimes we get as many as six separations. We can take those vibrations with a rule and can get what we think is a good test. It takes about half an hour to settle clear up. We have made vibration tests where we could even separate the iron. In that way you can derive a sample for testing which is a fairly good one.

We use that vibrating sample then for the analysis. We make six vibration tests to a car. There may be some variation. We get the nearest and best mixture from the average.

MR. HARVEY: That method would not be at all suitable for mixtures of silica cement or for finely ground fire clay in which you put a certain percentage of calcine. For example, the calcine does not grain as fine as the soft clay unless it is ground separately and your vibrator method would separate the calcine, put it at the bottom—whichever goes to the bottom—and any sample that you took from the center of the tube would not be representative of the shipment.

Question

Can a customer form any judgment of the quality of a shipment by a test made on one brick? If not, how many samples should be used?

Discussion

MR. NESBITT: The final analysis is what you get out of service. We cannot test all the brick we get. We have to start some place. We

usually select ten brick out of ten thousand as a representative sample. We get a car of fifteen thousand brick and we take fifteen brick. We try to get good representative brick, we try not to pick the worst or the best. That is our method at the present time.

CHAIRMAN: Do you find that method gives you satisfactory tests which check the service you expect?

MR. NESBITT: We have gone over failures in furnaces and run various tests on them and we find some tests indicate when the service is going to be good and when it is going to be bad. We have found that we can foretell whether this carload of brick is going to give an average life service or whether it is going to be a true failure. We do not say we can do that all the time, but it indicates.

MR. ROSS: I think we cannot lay too much stress on the great value of what Mr. Nesbitt said here—that it ought to give nearly relative results for anybody to use one brick per thousand. His long experience with that would indicate he seems to hit average practice with that number of samples.

MR. HARVEY: Are we to take from this, then, the assumption that one brick does not give us any result? I think that perhaps is what was intended to be brought out here. Every manufacturer frequently runs into complaints and when he traces them down he finds perhaps only one brick out of a shipment has been tested.

MR. NESBITT: Mr. Harvey, I said ten brick out of ten thousand. Ten brick is our minimum.

MR. HARVEY: But this question says—Is one brick from a shipment satisfactory?

MR. NESBITT: Absolutely no.

One method which we have been using is when we receive a carload of brick which looks as though it might be desirable, we take out about twice as many brick as we expect to test. We test the other half and send back to the manufacturer one-half if our own tests do not look satisfactory so we have the manufacturer checking us as well as our check on the manufacturer.—C. P. SPANGLER, Jones-Laughlin Steel Co., Pittsburgh, Pa.

A customer cannot judge a shipment of fire brick by a test of one brick. It is difficult to determine exactly how many brick should be tested, but the results of investigation made by Committee C-8 of the American Society for Testing Materials would indicate from ten to twelve. This, however, is usually impossible where shipments are numerous. In most cases, three or four bricks, picked at random, for each test will give a fair idea of the quality of the shipment.—E. N. MCGEE, The Semet-Solvay Co., Syracuse, N. Y.

ACTIVITIES OF THE SOCIETY

PRESIDENT'S PAGE

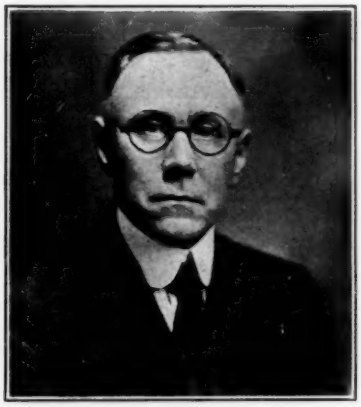
By Robert D. Landrum

August Staudt, Vice-President

The Board of Trustees of the American Ceramic Society announce the appointment of August Staudt of Perth Amboy, N. J., as successor to Raymond M. Howe as vice-president of the Society. This appointment came as a unanimous decision of the Board. The following sketch is taken from the History of Middlesex County, New Jersey, published 1921.

Captains and leaders of industry in their respective lines almost invariably are self-made men. Their lives blend closely with romance, giving an inspiring example of just what energy, perseverance and ability can accomplish. Success becomes part of their everyday activities, and each year is like a stepping stone to still greater and more pronounced achievements.

August K. Staudt stands prominent among the leading citizens of Perth Amboy, New Jersey, and a brief résumé of his life reflects well-earned regards in his chosen field. Tireless energy and broad public-spirited benevolence have been the keynotes of his success, and his notable progress in local circles indicates still more marked distinction in his activities in the time to come. His career is an inspiration.



August Staudt

He was born in Nuremberg, Bavaria, Germany, on December 6, 1869. He was the second child of Conrad and Rosa Staudt in a family of eight children, four boys and four girls. Receiving his education in Germany, and satisfactorily fulfiling his military duties in the Bavarian army, he left his native land in 1891. The five years following were spent in England, America and France, and in this time Mr. Staudt perfected his training as a correspondent in foreign languages.

Upon his return to Nuremberg in 1896, Mr. Staudt became connected with a large local industry, and a year later in 1897, married Katherine P. Vorgang, of Brooklyn, New York, whom he had met on his visit to America and who, in the year noted, was visiting relatives in Germany. Mr. Staudt was soon made superintendent of the Nuremberg factory, but relinquished this position in 1901 to take up a residence with Mrs. Staudt in America.

After occupying a number of important positions in banks and commercial houses, Mr. Staudt associated himself with the Perth Amboy Tile Works, and became a resident of this city. The plant at that time was practically unknown and quite insignificant while the company itself had just been reorganized. It was not long before unexpected difficulties arose, and in order to safeguard the investment he had made, Mr. Staudt was compelled to assume the full management of the small tile factory. He was undismayed, however, despite the fact that his working knowledge of ceramics was quite meager, and with grim determination he resolved to build up the establishment, if possible in any way, and make it one of the successful enterprises of the community.

He took a hand in affairs immediately, donning his overalls and tackling any job that needed to be done. Nothing was too hard for it was a case of necessity and resolve—the plant must flourish. Mr. Staudt established a definite working policy for the organization. He rebuilt what remained of the little defunct plant on the solid foundation of honor and integrity in business—the best products at the right price, and the same treatment of every customer, whether large or small. These principles live with the business now, just as they did in the early days, and they are one of the secrets of the remarkable success which the industry has attained.

Step by step the business thrived and then came into its own. The success has been spectacular, and due to the guiding hand and persevering energy of Mr. Staudt, the plant was developed and extended from year to year, and today occupies a position as one of the most modern and best equipped ceramic plants in the State of New Jersey. The floor space has grown from 6784 square feet to close to 42,000 square feet, more than six-fold; even now, the capacity is taxed to the utmost to furnish the demands of customers, and still more expansion will be necessary in the future.[1] Mr. Staudt can well take pride in this achievement, for with the plant he has grown to enjoy an enviable position among the leading business men in the state. In his treatment of his employees he has shown that he has at heart their utmost welfare and security; he has assisted them to purchase homes for their families, arranging large yearly bonuses for faithfully performed duties. Moreover, he has taken out a large block of building and loan stock for operatives at the plant without their knowledge, and which, when due, will be given to deserving employees.

Mr. Staudt has been a member of the AMERICAN CERAMIC SOCIETY, since 1911; past president of the New Jersey Clay Workers' Association and Eastern Section of the AMERICAN CERAMIC SOCIETY, and has long occupied a position on the board of directors of the latter organization. He is a thirty-second degree Mason, a member of the East Jersey Club, Raritan Yacht Club, Elks Club and other well-known organizations. His name will also be found in the membership list of many worthy societies, giving them the benefit of his support and influence.

Mr. and Mrs. Staudt have one child, Augusta, who was born in Newark, New Jersey, August 16, 1906. The family are members of the Evangelical Lutheran Church.

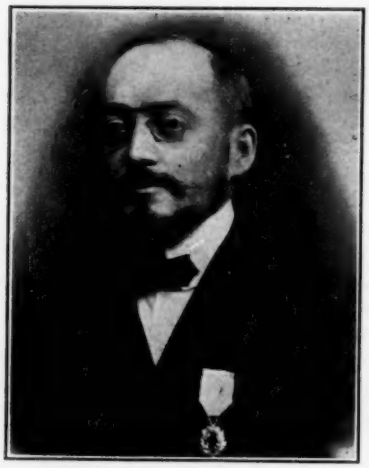
Dr. Julius Grünwald

The members of the Enamel Division will regret indeed to learn of the death of Dr. Julius Grünwald on April 11, 1924. Dr. Grünwald has done a great deal for the enameling industry, and especially for the enameling industry in this country and England, since his treatises on enameling were the first to be translated into English. The Enamel Division of the AMERICAN CERAMIC SOCIETY two years ago awarded Dr. Grünwald a purse for the work he had done for enameling.

"Dr. Ing. Julius Grünwald, born in Vienna on April 23, 1873, came from humble parents. He spent the first years of his life at Steyr (Upper-Austria) continuing his studies at Linz where he finished them in 1891. In the following 5 years he was immatriculated at the Technical High School at Vienna and Brunn, leaving that school in 1897 and taking a position as assistant to the University of Brunn (general chemistry). He then also had a position in the Enameling Works and Metal Manufacturers "Austria" at Brux and Brunn.

[1] Present floor space 79,124 sq. ft. plus 7 sixteen-foot kilns, Jan. 2, 1924.

From 1901–1905 he was engineer in the greatest European Enameling Works Thale at the Harz (Germany). In 1905 he took a position as director of the great enameling work Japy Freres and Co., Lafeschotte (France), from 1912 he entered on a regular course of correspondence with French, English and American, Swiss and other enameling works. He fluently spoke French, English, German, Czech and Hungarian. Though working for the benefit of the works he was connected with and doing a great amount of private scientific writing he nevertheless devoted his spare time for preparing himself for his final examinations writing a dissertation (New Methods for Pickling and Glowing of Steel and Iron) to take his degree which he did in 1910. He then was appointed technical chemist and sworn expert of the enameling industry to the Austrian Board of Trade. In 1913 he became sworn interpreter for French with the Court of justice in Vienna. At the International exhibition at Nancy he received the Great Golden Medal and received the title of an officer in the French Academy (Paris).



Dr. Julius Grünwald.

During the war he acted as expert at the "Metallzentrale" (State Organization for Metal Goods). Thereafter he established himself at his own office in the center of the town doing much investigatory work furthering the ends which are also the object of this society carrying on an enormous amount of correspondence with enameling works, societies and friends in all parts of the world. He married in 1919.

But his physical being could not stand the stress of many years strenuous, incessant work, the more so as he never would hear of rest and repose. So at last it gave way, terrible fits at intervals took their grip upon him and on April 11th while walking home an apoplexy struck him down in the street."

Besides publishing articles on enameling in every journal and trade paper in Germany, and in foreign journals including our own, Dr. Grünwald is the author of the following books which have been translated into many languages:

"Theory and Practice of Enameling on Iron and Steel," "The Technology of Iron Enameling and Tinning," "Chemical Technology of the Enamel Raw-Materials." Your President especially feels the loss of Dr. Grünwald, for Dr. Grünwald was a warm personal friend of his, and for many years he has been in close touch with Dr. Grünwald's work.

THAT ANNUAL MEMBERSHIP INVENTORY

We told you in the May *Journal* that May 1st was the time of taking a physical inventory of members and dropping of the "no response" group. This sort of pruning is always good for the plant—but my, how we hate it.

The total number of members shown on the membership curve for 1923 was 2241. This means that our net loss in number of members since December 14 is 118.

It is evident that we shall have to have Miss Norah Binns manage this field event. At this season she would be having a whole flock of home runs, boggie scores and nine-second sprinters. She was a most winsome promoter. Under her inspiration there were wins for all and then some. It is safe to believe that as she scans this page she

will be sorely tempted to forsake her "Box of Books" in little old Alfred and return again to the game.

Here is the count to date:

	Personal	Corporation	Total
Net Roster April 14	2020	300	2320
Dropped	209	12	
Net Roster May 14	1811	288	2099
New Members	25	4	
	1836	292	
Resigned	4	1	
Changed to Corporation Member	1		
Net Roster May 14	1831	291	2122

The gross acquisitions in members last year were 452 persons and 85 corporations. The gross acquisitions for 1924 so far by months are:

	Personal	Corporation	Total
January	31	6	37
February	40	8	48
March	29	0	29
April	35	3	38
May	25	4	29
	160	21	181

This means that if last year's record is to be equalled we will have to interest at least 291 more persons and 64 more corporations. 42 personals and 10 corporations per month will turn the trick and bring satisfaction to Miss Binns. Will you do your best?

NEW MEMBERS RECEIVED FROM APRIL 15 TO MAY 15

PERSONAL

Blackburn, H. A., 1450 Rockway Ave., Lakewood, Cleveland, Ohio, Norton Co. Sales.
Blatt, S. F., Prizer-Painter Stove Works, Reading, Pa.
Bonesteele, Sarah H., Victor, N. Y.
Boyne, P. K., 33 Beresford Ave., Highland Park, Detroit, Mich., Ford Motor Co.
Collings, William Arthur, P. O. Box 286, Santa Monica, Calif., Manager, W. A. Collings Co.
Crumley, F. S., 407 Johnson Street, Hammond, Ind., President, Indiana Sanitary Pottery Co.
Ekstrand, E. W., 786 E. Washington, Los Angeles, Calif., Engineer, Whiting-Mead Pottery Co.
Gill, Francis D., % Gill Glass Co., Philadelphia, Pa., President.
Johnson, A. G., 116 Hyland Ave., Ames, Iowa (Student).
Kauffmann, Otto Adolf, Niedersedlitz, Sa., Germany, Partner of Chemische Fabrik, etc.
Kelly, Walter H., Bethlehem Steel Co., Bethlehem, Pa., Refractory Engineer.
Kern, Edward F., % School of Mines, Columbia University, New York City.

Kuechler, Adolph H., 50 Richards Road, Columbus, Ohio (Student).
Maguire, Joseph, 440 Martel St., Bethlehem, Pa. (Student).
Murray, Ernest L., 43 Lewis Street, Perth Amboy, N. J., Plant No. 2, Atlantic Terra Cotta Co.
Nichols, Mrs. George, Syosset, Long Island, N. Y., Syosset Pottery.
Ouffner, Abiram A., 107 Milford St., Mount Union, Pa., Harbison-Walker Ref. Co.
Pegram, James, Carrollton, Ill., Pegram Clay Co.
Peterson, T. J., President Tamms Silica Co., 30 N. La Salle St., Chicago, Ill.
Schmid, Fred, 395 Riley Street, Buffalo, N. Y., Clay Salesman, Butler Clay Co.
Stilson, Alden E., U. S. Bureau of Mines, Ceramic Experiment Station, Columbus, O.
Suydam, Albert G., 405 Hobart Bldg., San Francisco, Cal., Pacific Coast representative, Harbison-Walker Refractories Co.
Tombaugh, R. S., Waukegan, Ill., Chief Engineer, Franklyn R. Muller, Inc.
Weaver, Harry F., Evansville, Ind., Secy., and Gen. Mgr., National-Helfrich Potteries Co.
Zandstra, J. J., % Harshaw, Fuller & Goodwin Co., 107 N. Market Street, Chicago Ill., Salesman.

CORPORATION

Cambridge Sanitary Mfg. Co., D. Keith McAfee, Vice-President, Cambridge, Ohio.
The Ceramist, L. R. W. Allison, Editor, 170 Roseville Ave., Trenton, N. J.
Lancaster Iron Works, Inc., Jas. P. Martin, Mgr., Lancaster, Pa.
Pacific Stoneware Co., Thomas S. Mann, 695 Sherlock Ave., N., Portland, Ore.

Membership Worker's Record for May

	Personal	Corporation		Personal	Corporation
L. R. W. Allison		1	W. G. Owen	1	
Paul E. Cox	2		W. F. Rochow	1	
M. A. Gesner	1		Chas. W. Saxe	1	
Ralph E. Hanna	1		Mary G. Sheerer	1	
F. A. Harvey	1		R. R. Shively	1	
H. A. Huisken	1		F. W. Walker, Jr.	1	
Roy A. Horning		1	W. W. Wilkins	3	
Walter M. Hughes	1		Office	8	1
T. S. Mann		1		—	—
R. L. McGean	1			25	4

PITTSBURGH LOCAL SECTION

The Pittsburgh Section of the AMERICAN CERAMIC SOCIETY held their regular monthly meeting on Friday evening, May 16, at the Bureau of Mines, Forbes Street, Pittsburgh, Pa. This meeting was one of the most enthusiastic and profitable of any which this Section has held. Following a cafeteria dinner at 7 P.M. the following program was given.

Henry M. Taylor, of the H. C. Fry Co., of Rochester, who is conducting experiments on the dielectric properties of special glass, talked on the development of heat-resisting glass. Examples were shown of high-voltage insulators, sparking plugs and oven ware.

E. H. McClelland, Technician and Librarian of the Technology Department of

Carnegie Library told the members from what source they can follow up this subject at the Library. Mr. McClelland has listed the references on porcelain, among them a number of articles on insulator practice, their design and tests for high voltage currents.

R. E. Arnold, of the Research Department of Westinghouse Electric and Mfg. Company, talked on the development of high-voltage insulators. Mr. Arnold, in conjunction with R. V. Weber of the same company, has had much to do with the development work and tests on insulators and his talk was highly profitable.

The members of the Pittsburgh Section were invited to attend the meeting of the Pittsburgh Section of the American Chemical Society held at Carnegie Lecture Hall on May 22. Harrison E. Howe, Editor of *Industrial and Engineering Chemistry*, talked on "Chemistry in the Nation's Business."

SCHEDULE AND ASSIGNMENTS FOR 1924 SUMMER TRIP

Congregate in Chicago at La Salle Hotel, July 21. Leave 11 P.M. Monday, July 21, on C. M. & St. P. R. R., Union Station.

Spokane, Wash.	July 24. Breakfast, Davenport Hotel. Lunch at Mica. Dinner at Country Club. Local committee will make all arrangements.
Seattle, Wash.	July 25. Arrive 11:45 A.M. Leave Monday, July 28, 11:45 P.M. New Washington Hotel. Banquet in the evening. Local committee will make all arrangements. July 28. Optional trip to Mt. Rainier. Arranged by local Committee.
Portland, Ore.	July 29. Arrive 6:45 A.M. Leave 9:00 P.M. same day. No hotel. Arrangements by local committee.
Lincoln, Cal.	July 31. Arrive 3:15 A.M. Leave 5:20 P.M. same day. No hotel. Arrangements by local committee.
San Francisco, Calif.	July 31. Arrive 10:05 P.M. Leave Sunday, August 3, 11:00 P.M. Palace Hotel. Arrangements by local committee.
Merced and Yosemite	Aug. 4 and 5. Arrive 5:00 A.M. Leave Aug. 6, 8:30 P.M. The hotel and trip arrangements for these three days will be made by the Chicago, Milwaukee & St. Paul Railway Co.
Los Angeles	Aug. 7–13 inclusive. Arrive 7:55 A.M. Hotel Clark. The local committee will make all reservations and all side trip arrangements.
Grand Canyon	Aug. 14. Arrive 8:20 A.M. Leave 7:25 P.M. Arrangements and reservations will be made by the railroad.

Denver, Colo.	Aug. 16. Arrive 12:00 noon. Leave 7:40 P.M. Arrangements made by local committee.
Colorado Springs, Colo.	Aug. 16–17. Arrive 10:10 P.M. Aug. 16 and leave 10:15 P.M. Aug. 17. Antlers' Hotel. Arrangements by local committee

NOTES AND NEWS

BUREAU OF MINES NOTES

Cyanite

Cyanite, a mineral identical in chemical composition with andalusite and sillimanite, but differing in crystal form, has not yet been exploited to the same extent as andalusite, but has many interesting possibilities, states the Department of the Interior, in Serial 2587, recently issued by the Bureau of Mines. Deposits believed to be of commercial importance are reported at a location about twenty miles southwest of Wheatland, Wyoming, and near Charlotte Court House, Virginia. The latter deposit is being developed at present. The commercial possibilities of cyanite are not yet fully known. Like andalusite it inverts to sillimanite when heated to high temperatures, and possibly may be used to produce sillimanite for refractory purposes.

Preparation of Super-Refractories

An investigation having for its purpose the production, by electric furnace methods, of materials of higher refractoriness than those commonly used in commercial practice is being conducted by the Department of the Interior at the Seattle, Wash., experiment station of the Bureau of Mines. Such refractories have been called super-refractories. The first material to be investigated is sillimanite. Two methods of preparing the material are being studied, namely, (1) From a mixture of clay and aluminum oxide in the form of bauxite, diaspore, or alunite residue; (2) From clay alone by removing the requisite amount of silica and the iron by melting with carbon in the electric furnace. The material thus produced in the electric furnace is then subjected to the methods of testing refractory materials and is fashioned into brick and other shapes and given both refractory and commercial tests.

Encouraging progress has been made in this investigation. It is expected that the work on sillimanite will be completed during the present fiscal year and that another material will be taken up.

Spinel

Spinel is a magnesium aluminate occurring in different colors, chiefly red, blue-green and black. Spinel has been found in many scattered localities in small amounts; deposits of sufficient size to have an economic significance are not known to occur. Spinel has never been used commercially except the rare transparent blue and red varieties which have been used as gems.

While the natural spinel has been of little economic value, it is interesting to note that an artificial spinel, produced by synthesis from its compounds displays very interesting commercial properties. This synthetic spinel is made by the combination

of magnesium oxide from magnesite and aluminum oxide from the mineral alunite, which occurs in large quantities at Marysvale, Utah. During the world war when imports of foreign potash were cut off, these deposits of alunite were exploited for their potash content. The mineral was first roasted, rendering the potash soluble so that it could be extracted by leaching. The aluminum oxide content of the residue after leaching was approximately 95 per cent. The synthesis is accomplished by electrical fusion, the spinel appearing in beautifully crystallized masses. This material when bonded in the form of bricks possesses remarkable refractory properties which have made it valuable for many commercial purposes.

Information regarding spinel and various other little known non-metallic minerals is contained in Serial 2587, copies of which may be obtained from the Department of the Interior, Bureau of Mines, Washington, D. C.

BUREAU OF STANDARDS NOTES

Test for Alkaline Glassware

Recently a proposed test for the detection of alkaline glassware was carried out by the Chemistry Division of the Bureau. The test consisted in heating the sample in an autoclave at 15 pounds steam pressure for one hour. In the case of the best chemical glassware, water held in the beaker was still neutral to phenolphthalein after the test. Other ware gave results ranging from a very faint alkaline solution to solutions which were decidedly alkaline and were accompanied by considerable insoluble matter. In the last-named cases some of the ware was badly etched.

The Bureau believes that this test is satisfactory for the purpose intended.

"Consistency" as Applied to Sluggishly Flowing Material

The following is an abstract of an article on "Consistency" prepared by W. H. Herschel of the Bureau of Standards at the request of Dr. Jerome Alexander for use in his book "Colloid Chemistry, Theoretical and Applied."

In speaking of a material which will flow sluggishly, it is often said that it has the consistency of rich soup or thick cream. Thus the word consistency has a well-known colloquial meaning, and it may be used as a general term when speaking of soft solids and liquids.

It has been found experimentally when testing what may be called true or viscous liquids, that the rate of flow is proportional to the force which produces it. Other materials may flow quite readily, and yet be soft solids or plastic materials which do not show the constant proportionality above referred to.

It is only recently that it has been realized that many common materials, such as paint and mixtures of clay and water, are plastic and not viscous, and much confusion has resulted in colloidal chemistry from the failure to make this distinction. No method of measuring consistency has proved entirely satisfactory for stiff clays and fats, but it is at least possible to determine which materials are plastic, and to measure the plasticity of many plastic materials which are sufficiently fluid.

In cases of doubt tests should be made at more than one rate of flow, and if the numerical results vary, showing that the material is plastic, the attempt should be abandoned to express the consistency of the material by a single numerical value called "viscosity." Two laboratories, by using standardized apparatus and the same rate of flow, may obtain the same "apparent viscosity" for a plastic material from a single test, but it is important to observe that to identify the consistency of a plastic material it is necessary to make at least two measurements at different rates of flow.

Methods and Materials for Lining Tanks with Tile

An investigation is being carried on for the Associated Tile Manufacturers to determine the proper methods and material for lining tanks with tile. During the past month six more concrete tanks have been made. Nos. 123 to 127, inclusive, have been lined with vitreous tile and the corresponding sets of tile bars for transverse strength tests have been made. The grouting cement was a so-called natural cement. Tank No. 119 of this series has now been filled with photographic fixing solution; tank No. 120 with photographic developer; while Nos. 122 and 123 have been filled with sulphurous acid (saturated solution). The effect of these solutions on the linings of the tanks will be studied.

DEPARTMENT OF COMMERCE NOTES

Fourth Reduction in Vitrified Paving Brick Adopted

After having made a comprehensive survey of demands for various sizes of vitrified paving bricks for 1923, the permanent committee on simplification of varieties and standards in that industry met Friday in the Division of Simplified Practice, Department of Commerce, and voted to adopt the fourth reduction in sizes and types since simplification was begun in 1921.

The committee, comprising Will P. Blair of Philadelphia, of the American Society for Testing Materials; Col. R. K. Compton, of New York City, representing the American Society of Civil Engineers and the American Society for Municipal Improvements; Edward E. Duff, Jr., of Cleveland, Ohio, representing the National Paving Brick Manufacturers' Association; Leon C. Herrick of Columbus, Ohio, representing the American Association of State Highway Officials; E. W. McCullough, of the Fabrication Production Department of the United States Chamber of Commerce; E. J. Mehren, of the McGraw-Hill Co., New York City; O. W. Renkert of Columbus, Ohio, representing the AMERICAN CERAMIC SOCIETY and P. St. J. Wilson of the Bureau of Public Roads, Department of Agriculture, found that for 1923 the demand for the six recognized varieties had comprised 80.3% of the total business. The size which was eliminated at today's sessions was found to take up but nine-tenths of 1% of the demand for the same period.

When the paving brick industry first undertook simplification in November, 1921, the 66 sizes then made were cut to 11. At later meetings of the permanent committee on simplification, this number was reduced to seven, and then six, the latter number having stood the test of a year's survey with the results indicated.

This industry was one of the first to seek the coöperation of the Department of Commerce after Secretary of Commerce Hoover initiated the movement for simplification as an aid to American industry. Among the benefits which have been reported through its action are: reductions in cost of production, improved service, and ability to compete more effectively with producers of other types of paving materials.

SOCIETY OF GLASS TECHNOLOGY

The seventh Annual General Meeting of the Society was held in Sheffield on Wednesday, April 16, 1924, the President, Prof. W. E. S. Turner, in the chair. Col. S. C. Halse (Messrs. J. Lumb & Co., Ltd., Castleford) was elected President in succession to Prof. W. E. S. Turner. The other vacancies arising were filled as follows: *Vice-Presidents*, F. G. Clark (Messrs. Beatson, Clark & Co., Ltd., Rotherham), R. L. Frink

(Glass Research Association, London). *Members of Council*, H. A. Bateson, W. R. Dale, J. Moncrieff, W. J. Rees, J. H. Steele, and H. Webb. *Honorary Treasurer*, J. Connolly. *American Treasurer*, Wm. M. Clark. *Honorary Secretary*, S. English. *Auditors*, Ed. Meigh, and Dennis Wood.

The Annual Report and Accounts for 1923 showed that year to have been a happy and successful one. The foreign membership continued to increase, numbering 190 out of 615 at the end of 1923. Of these 109 were resident in the United States. Altogether the Society was connected by membership with no fewer than 17 countries. Prof. Henry Le Chatelier, Paris, was elected an Honorary Member of the Society. A paper entitled "The Physical Properties of Some Alloys Resistant to Heat and Corrosion" was read by J. H. G. Monypenny, and illustrated by lantern slides and specimens. The author dealt with problems which might occur in machinery pertaining to the glass industry, and said there were also certain general engineering uses for material having these special properties, such as the application of the material to various fittings for steam service and hydraulic work.

Dealing first with stainless steel, he outlined the range of properties obtainable, dwelling also on the mechanical and heat resisting properties. Passing on to alloys developed for special properties, the lecturer gave particulars of stainless material in which resistance to mineral acids had been greatly increased, and the tendency for galvanic action in contact with bronze and other copper alloys entirely removed. A short description of some special alloys which had been developed for resisting scaling was given. A sample exposed in a brick kiln for a fortnight, the temperature reaching 1,200°C revealed a total change in weight of only .04%. The glass industry required alloys suitable for a number of special purposes, in some cases for resisting general corrosion, and in others for resisting the effects of high temperatures. Probably no single alloy would be suitable for all purposes, though for any of those purposes some type of stainless steel would be found useful. For developing any one special property in an exceptional degree, it was generally found necessary to sacrifice other properties to some extent, so that it was advisable for the maker and the user to collaborate.

Mr. W. R. Barclay followed with a paper entitled "Some Properties and Possible Industrial Uses of Alloys Containing Nickel." Illustrating his remarks with lantern slides Mr. Barclay said that he proposed to deal with two alloys, the simple nickel-copper series and the nickel-chromium series, with no other metals added. Referring to the nickel-copper alloys he emphasized their remarkable ductility, combined with considerable toughness and strength, and very considerable resistance to corrosion. A retention of strength at temperatures higher than those at which ordinary non-ferrous metals break down was particularly evident in the nickel-copper alloys containing high nickel. As an illustration of the enormous ductility, he quoted a recent example of material manufactured, in which it had been possible to cold-work a 2 in. bar right down to .02 in. without annealing.

Going on to deal with the nickel-chromium alloys, he pointed out that the two hitherto developed were the 85% nickel, 15% chromium, and the 80% nickel, 20% chromium. They were remarkable materials, bridging the great gulf that had hitherto existed between ferrous and non-ferrous materials, and combining in a high degree the best properties of both. These were the alloys which had made modern developments of electric heating possible. A very important application of them, which the immediate future would see unquestionably, was their use in annealing furnaces where temperatures up to that order were required.

During the morning an exhibition of special steel and non-ferrous alloys, and of tools and plant made from them, was held in the Department of Glass Technology of the University of Sheffield. The following firms exhibited:

Messrs. Brown Bayley's Steel Works, Ltd., Sheffield,
Cronite Foundry Co., Ltd., Tottenham, London,
T. Firth & Sons, Ltd., Sheffield,
Foster Instrument Co., Ltd., Letchworth,
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The President announced that the next meeting would be held in London on May 27th when a joint conference had been arranged with the British Society of Master Glass Painters. They also expected to welcome on that occasion a party of members from France. The Annual Dinner would be held on the evening of May 27th in the Hotel Cecil, London.

A FRENCH MONTHLY REVIEW

A new monthly review was started in November, 1923, entitled *"La Revue Generale des Colloides et de leurs Applications Industrielles."* Hitherto no French publication has specialized in the study of colloids, the importance of which in industrial technic is constantly increasing. Processes resulting from the theory of colloids may revolutionize certain industries now using empiric and routine methods. The development of colloid chemistry being very recent, most of those engaged in industry will be interested in reading this new review. Original articles will appear each month as well as a narrative containing extracts of all the work that has appeared and French, English, American and German abstracts divided into twenty-four classes.

CALENDAR OF CONVENTIONS

Organization	Date	Place
AMERICAN CERAMIC SOCIETY (Summer Meeting)	July 21–Aug.—1924	Trip to Pacific Coast
AMERICAN CERAMIC SOCIETY (Annual Meeting)	Feb. 16–21, 1925	Columbus, Ohio
Am. Foundrymen's Assn.	Oct., 1924	
Am. Gas Assn., Inc.	Oct., 1924	
Am. Society for Testing Materials	June 23–27, 1924	Atlantic City
British Assn. for the Advancement of Science	August 6–13, 1924	Toronto, Canada
Chemical Equipment Assn.	Sept., 1924	
Colloid Symposium	June 19–21, 1924	Northwestern Univ., Evanston, Ill.
Eastern Paving Brick Mfrs. Assn.	Dec., 1924	New York (?)
Manufacturing Chemists' Assn.	June, 1924	New York
Natl. Glass Distributors' Assn.	Dec., 1924	Pittsburgh, Pa.
Natl. Ornamental Glass Mfrs. Assn. of U. S. and Canada	June 24–26, 1924	New York
Natl. Paving Brick Assn.	Dec., 1924	
Refractories Manufacturers Association	June 23–24, 1924.	Atlantic City
Society for Promotion of Engineering Education	July, 1924	Boulder, Colo.
U. S. Potters' Assn.	Dec., 1924	Washington, D. C. (?)
Western Glass and Pottery Assn.	June 15, 1924	Pittsburgh, Pa.
Western Society of Engineers	June 4, 1924	Chicago, Ill.

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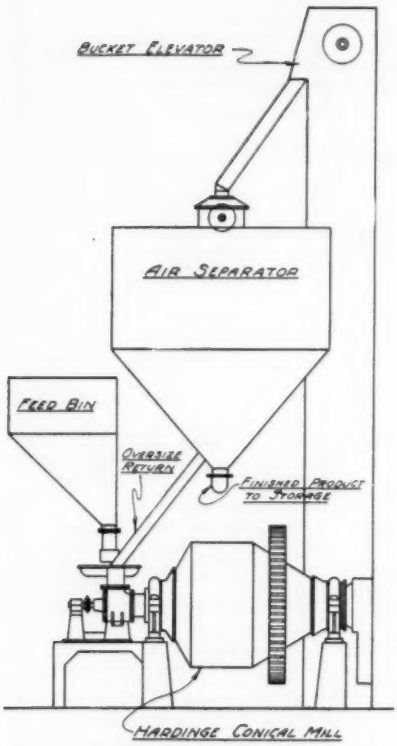

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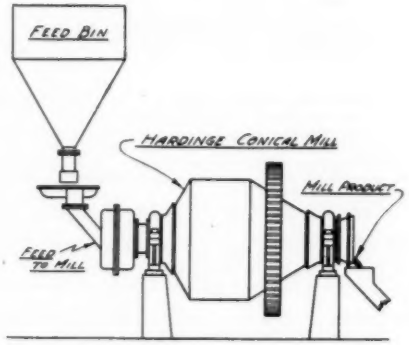

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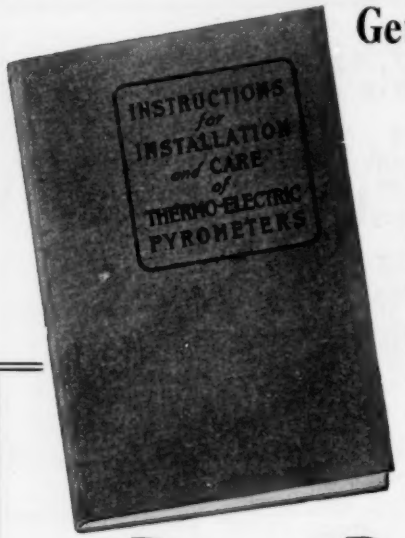

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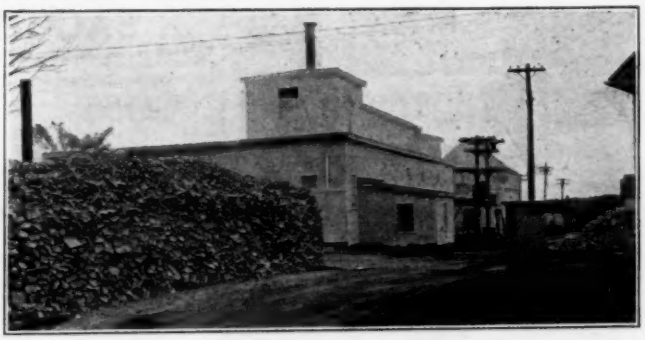

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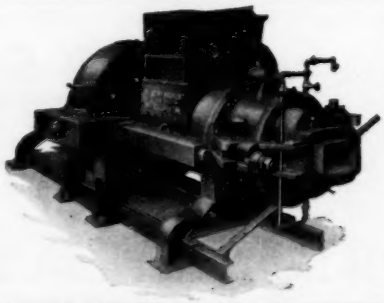

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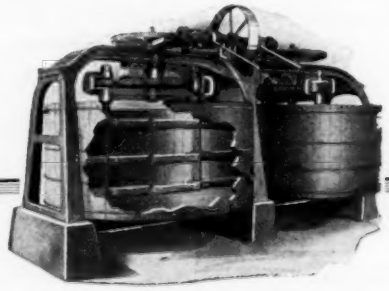

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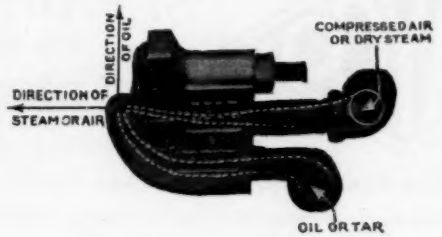

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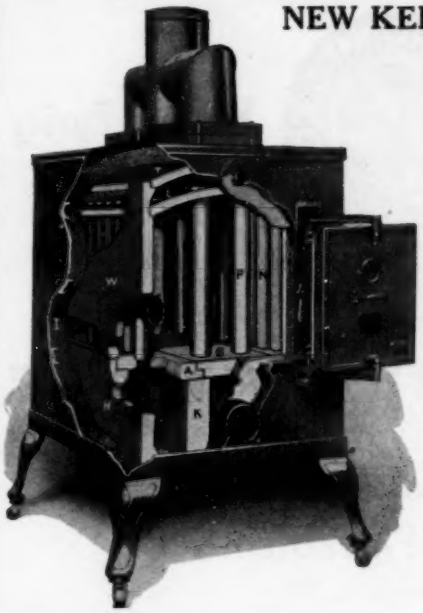

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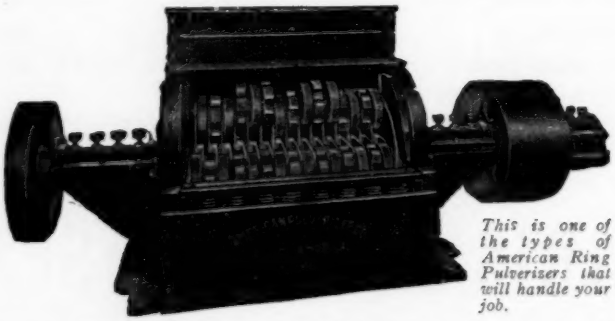

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